CAUGHT IN ACTION

ROTATING PRISMS
BENZENE SHUTTERS
IMAGE CONVERTERS

NOTHING IS MORE GRACEFUL than a gymnast or a dancer leaping through the air. The movement is so fast that the human eye cannot follow it – only a camera can freeze the action and capture that moment in time for ever.

In a normal camera, light reflected from the subject is focused by the lens and prevented from reaching the film by the shutter. When you press the button, the shutter opens and allows light to reach the film. The period of time that the shutter is open has to be matched to the speed of the movement being photographed.

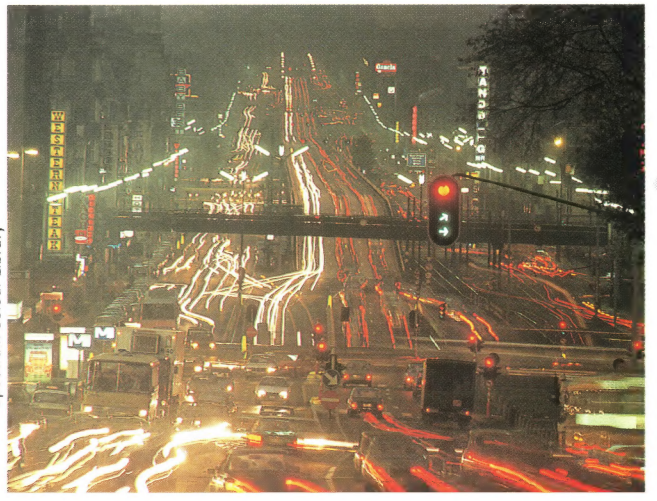
For example, inexpensive cameras usually have a fixed shutter speed of 1/60th of a second and can only freeze the movement of someone moving at walking pace. More sophisticated cameras have shutter speeds down to 1/1000th or even 1/2000th of a second.

However, for many specialized purposes, such as sports coaching or the study of fast-moving wild life, 1/2000th of a second is nowhere near fast enough. In that fraction of a second, an insect's wings could complete a whole beat so any photograph of the insect taken at that speed would just be a blur.

To freeze the action of a bird flying or a tarantula striking, an exposure time between 1/16,000th and 1/24,000th of a second is required. The fastest speed that can be achieved with a mechanical shutter is 1/4000th of a second, so some other way of making short exposures had to be found.

***Gymnast Pascal Eouzan** does a back flip, illuminated by a series of strobe flashes. All light is excluded from the studio and the background is non-reflective matt black so that it does not show up in the final picture.*

Split Second



Spectrum Colour Library

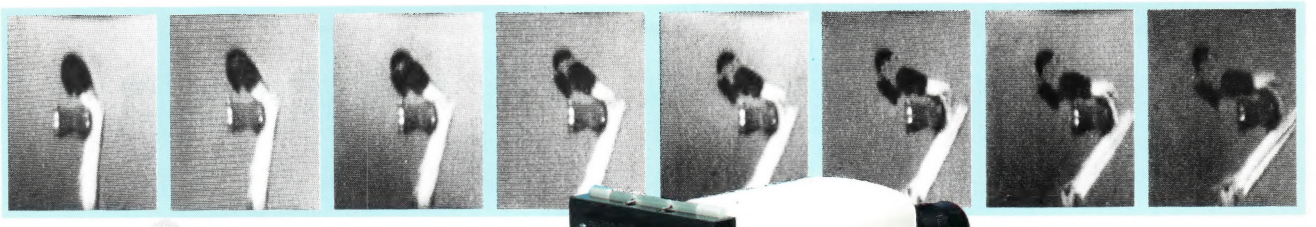
***Time exposures** are made by leaving a camera shutter open for a period of time ranging from one second to perhaps 12 hours. Any movement in the picture shows as a blur. This type of picture is useful for capturing a period of time in a single photograph.*

Short flashes

The simplest method found so far is to leave the shutter open and illuminate the subject with a very short flash of light. However, light can reach the film all the time that the shutter is open, so when using this method, pictures can be taken only in complete darkness.

Suitable flashes can be produced by a bank of electronic capacitors which shoot very high voltage electrical charges through a gas-filled tube. These discharge tubes can produce flashes as short as 1/24,000th of a second.

Since it is difficult to black-out a nest site or the branch of a tree, a lot of bird and insect photographs that look as if they were taken in the wild are actually taken in a studio. Alternatively they are sometimes taken at night, using black curtains draped around the tree branches to



Hadland Photonics

Image-converter Cameras *can take up to six hundred million pictures per second. This sequence of an air gun pellet breaking an ordinary matchstick was taken at only one hundred thousand pictures per second using an Imacon 792 camera (right). The pellet was travelling at 90 metres per second or 324 km per hour. The period of time covered by the sequence is eighty millionths of a second.*

Edgerton/Science Photo Library

Schlieren photographs *detect invisible pressure changes in gases. Here the bullet is moving so fast that it creates a series of shock waves.*

shut out any moonlight and as much starlight as possible. Hidden trip switches are often used to trigger the flash – so when an animal lands on a branch or pops out from its hole, it triggers the trip switch and photographs itself.

When studying things such as electrical sparks, it is often necessary to take a series of photographs so that scientists can study each stage of a very fast event. The simplest type of camera for this job is a rotating prism camera. These can take up to 25,000 pictures per second, while a similar design that uses a mirror in place of the prism can take one million pictures per second.

In rotating prism cameras, the light from the subject passes through a normal camera lens to a rotating prism. When the light hits the prism at a particular angle, it passes through and is focused on the film. As the prism turns it diverts the light away from the film, which can then move on one frame. The prism then continues to revolve until the next picture is taken.

The finished film is a sequence of frames rather like an ordinary movie film. The top speed of this type of camera is limited to 25,000 pictures per second because the rotation mechanism would break up into bits if it turned any faster.

Image-converter cameras are the fastest of all and can achieve speeds up to six hundred million frames per second. These are mainly used for studying the firing and impact of artillery shells and missiles.

Light is focused through a lens on to a photocathode device which converts the light into a beam of electrons. This is then focused on to a fibre-optic block which transmits the picture onto the film.

Electron beam

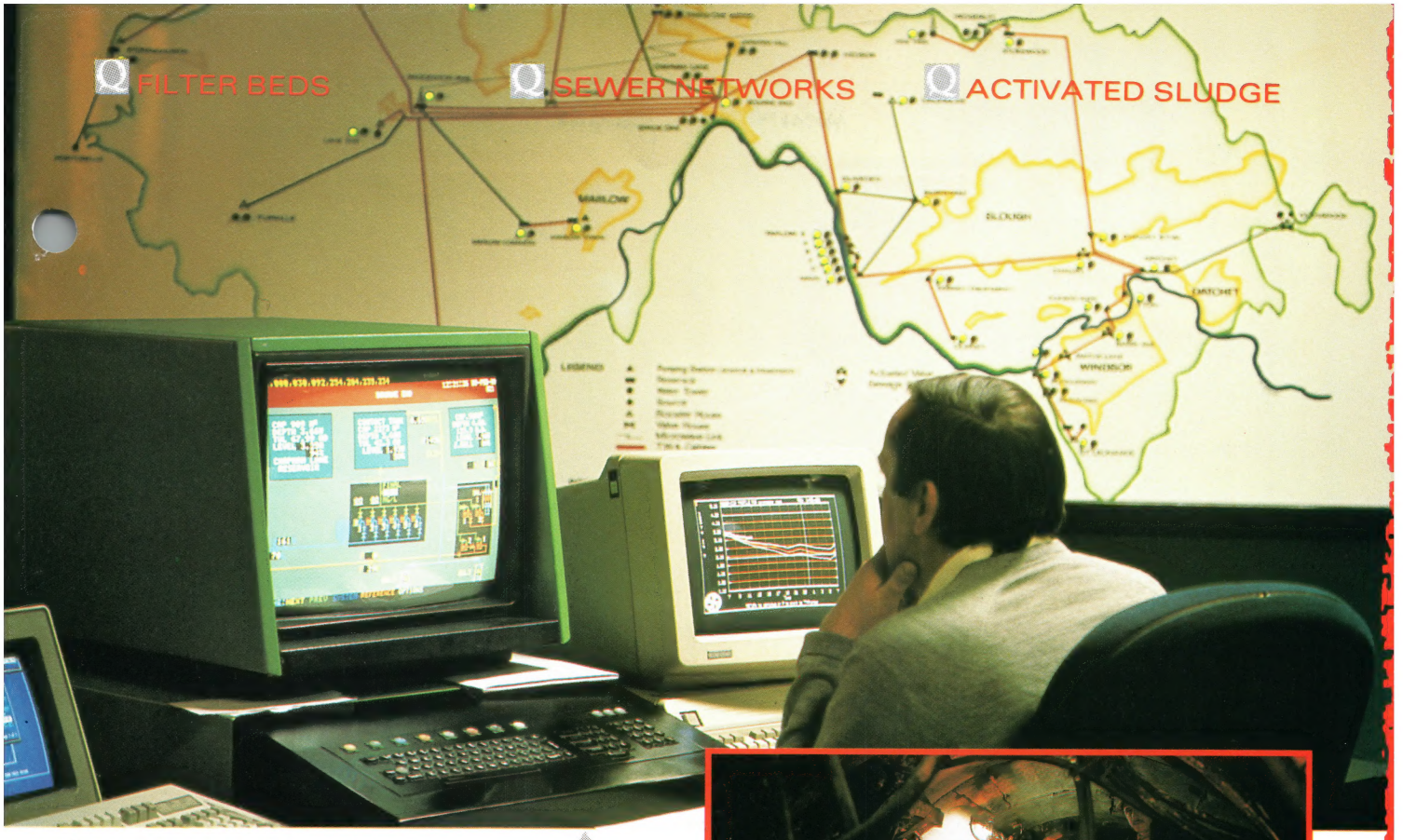
In a recent development of this technology, the electron beam is fed into a TV camera and the picture is viewed on a TV screen. If a permanent record is required, the TV picture can be photographed. This is extremely useful for research and development purposes.

SPEEDING UP TIME

Sean Morris/Oxford Scientific Films

Time-lapse photography is a way of compressing long periods of time on to a short length of film. If a cine camera shoots one frame per second, an hour's action is condensed into 2½ minutes. This short time lapse is used to record events that happen fairly quickly such as a crystal growing or chicks hatching out of an egg. A time lapse of one frame per hour is used to record slower processes, such as a flower blooming or a house being built. When screened, the whole process can be watched in a matter of minutes.

Paul Raymonde



Thames Water

Water supply *networks are being fitted with remote control systems so that one man can control many water treatment works.*

Tunnels *up to 2.5 m across are being built to keep large towns supplied with water. This one will be longer than the Channel Tunnel.*

Thames Water

WATERWORKS

SAFE DRINKING WATER IS vital for good health. Without it, most people would suffer from diarrhoea and sickness most of the time.

The microbes that cause disease do best when they have human waste matter – sewage – to live on. As eighty per cent of normal drinking water is pumped out of the rivers, it is vital to keep them free from human and animal pollution.

This is no problem at the start of a river. But towards the mouth, after all the waste water and chemicals from the factories and towns along the banks has been emptied into it, river water is usually heavily polluted. Nevertheless, there is nowhere else to get large supplies of water from, so to protect the people who drink it, many countries have legal controls on the:

- number of bacteria and other microbes
- number of pieces of solid human and animal waste
- quantity of dissolved salts in drinking water.

It is not easy to meet these standards because more and more human waste from inefficient sewage works and animal waste from factory farms gets into the rivers.

At a waterworks, the river water is first filtered through wire mesh screens to remove the rubbish. It is then pumped into reservoirs until required. These are stocked with fish, which makes them an angler's paradise. However, the real purpose of the fish is to act as a check that the water is clean.

When the water is drawn out of the reservoir, it is filtered through a series of beds containing sand. The sand in the first bed is quite coarse, so the largest particles of dirt are trapped there. The next bed contains finer sands and so on. During this process, some microbes are killed by exposure to the air and others get eaten by other microbes.

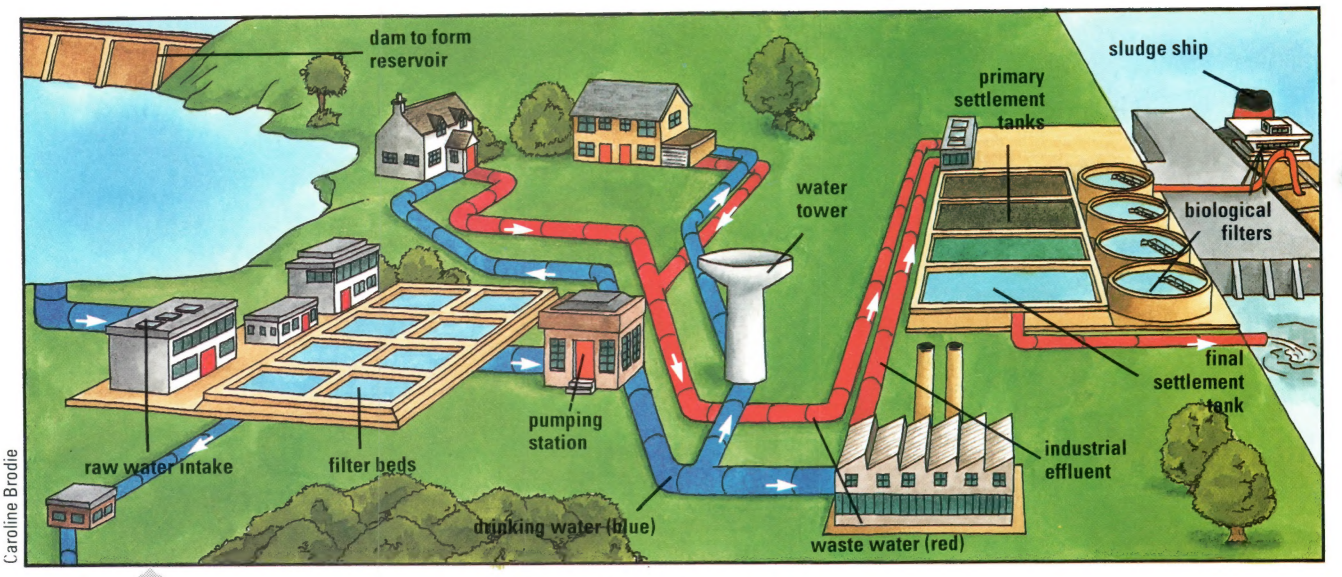
Nevertheless, there are nearly always some harmful bacteria left, which are dealt with by dissolving a measured amount of chlorine gas in the water as it leaves the waterworks. If you find the water from the tap at home tastes odd, that is probably the chlorine.

In hilly areas, the purified water is then pumped uphill into an underground holding reservoir. In flatter districts, the water is pumped into water towers around 30 metres high. When somebody opens a tap, the water rushes downhill, through the pipes and gushes out of the tap.

Electric pumps

Large towns use too much water to store in this way, and so large electric pumps force the purified water through a network of pipes to the consumers. Up to a quarter of the water leaving a waterworks escapes from leaks in this network.

Inside the house, small copper pipes carry water to the kitchen, the bathroom and the lavatory. When you pull the plug out, the water flows away through the waste pipe. The contents of the lavatory disappear into the soil pipe.



Caroline Brodie

Underground pipes *form a network joining up the various parts of the water and sewage system. The pipes are laid so that the water can run downhill from the reservoirs in the hills right through to the point where purified sewage re-enters the river.*

Yorkshire Water Authority

Electric pumps, *each one using as much power as a dozen small cars, feed purified water into the water mains serving a large town. The 'steering wheels' are for opening and shutting the enormous valves that turn the water on and off.*

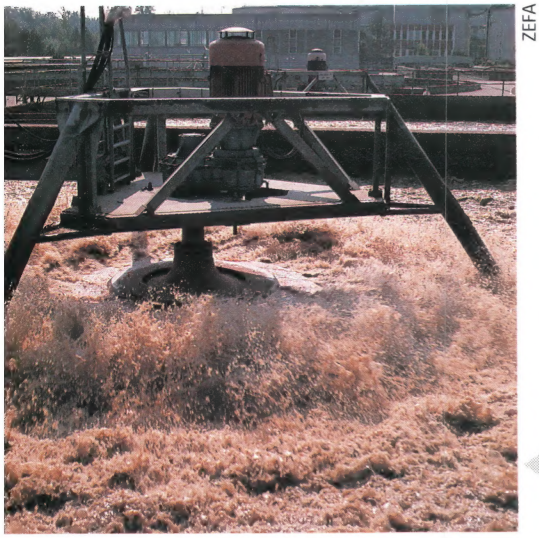
In modern houses, the waste pipes and the soil pipe connect with the soil stack, which runs up the outside of the house. This disappears into the ground, joins up with the house drains under the pavement and eventually meets the sewer which runs along the road.

The sewers serving each road join up into larger trunk sewers and eventually reach the main sewers which run into the sewage works. All the pipes are laid with a gentle slope down to the sewage works so that the flow of water carries the solid waste with it without pumping. Drains in the road also feed rainwater into the sewers.

Minced solids

At a sewage works, the first job is to remove the biggest bits of rag, tree branches and grit. Sometimes the sewage is then passed into a mincing machine which minces all the remaining solids until they are fine enough to go into the primary settlement tanks.

Here the solid sludge falls to the bottom of the tank and is removed for treatment elsewhere. The liquid sewage is then sprinkled on to a biological filter. These are beds of stone about two metres deep. So many bacteria live on the stones that the surface gets covered with a jelly made of billions of bacteria. As the liquid trickles through the filter, these bacteria eat most of the remaining waste matter.



ZEFA

Oxygen-breathing bacteria *eat and so purify the liquid sewage. Large paddles mix air into the liquid in the tanks to make sure the bacteria can breathe properly.*

Dead microbes

The water draining out of the biological filter is much cleaner than the liquid that flows in, but it still has to go through the final settlement tanks. Here, lots of dead microbes and algae sink to the bottom as sludge.

At some sewage works, the biological filter has been replaced by the Activated Sludge Process, in which a high concentration of bacteria is mixed with the incoming sewage. This mixture is then stirred up and air is mixed in with a set of electric paddles so that the bacteria breed rapidly and eat all the particles of organic matter in the water. Again this creates a sludge which requires more processing.

All the sludge in the sewage works is collected for treatment in one place. Sometimes bacteria are encouraged to eat the sludge, but it can also be used as a fertilizer. However, since various poisonous heavy metals like cadmium have been found in sewage sludge, it has tended to be dumped at sea or burnt. Both methods of disposal anger environmentalists, but as yet no ideal solution has been found to this age-old problem.

HUMAN WATERWORKS

Just like a waterworks with its beds of sand for filtering water, the human kidney is equipped with a million filter tubes called glomeruli. About 200 litres of plasma – the watery part of the blood – enters the kidneys every day through a large artery and the glomeruli filter out the waste. Most of the water, plus many useful substances like glucose, are returned to the blood stream while concentrated liquid waste – urine – is excreted.

MAKING TRACKS

IN THE STUDIO

THE RECORDING STUDIO IS the heart of today's music industry. And, with the ability to take a raw performance, correct mistakes, polish and improve it, it has, in many cases, also become the soul.

The studio is the link between the musician and the vast majority of his or her audience. Its most basic function is to record a performance on magnetic tape – the tape then being used to manufacture records, cassettes or compact discs.

The control room

There are two main parts of a recording studio – the 'studio', or room, where the musicians perform and the control room where the technicians operate the recording equipment. Both are soundproofed. This means that no unwanted noises can interfere with the recording and the technicians hear only what they want.

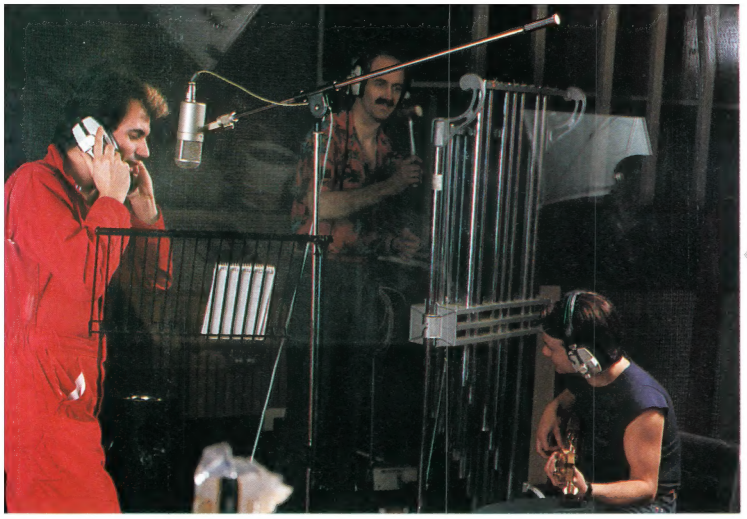
Some recording studios have electronic room simulators which can make an acoustically neutral room sound like a large or small concert hall – or even a bathroom. Some musicians, however, prefer to record in an acoustically 'live' environment. Stewart Copeland, drummer of the rock group The Police, for example, was known to record the drum tracks of Police records in rooms that he felt sounded 'right' for the particular song.

A song is normally recorded in stages – each musician performing his or her piece individually. The musicians may either 'read' their parts or play along to a 'guide track' – a rough recording of the complete

MAGNETIC TAPE

THE MIXING DESK

A 24-track mixing desk in a recording studio is as difficult to operate as a jet aircraft. It can record, adjust and combine up to 200 separate sounds



Gavin Cochrane

***A band** starts a recording session by recording a 'guide' rhythm and vocal track. The engineer feeds this via headphones to the musician or section he next wishes to record. The players 'lay down' their parts by playing to the guide, which is erased when the song is finished.*

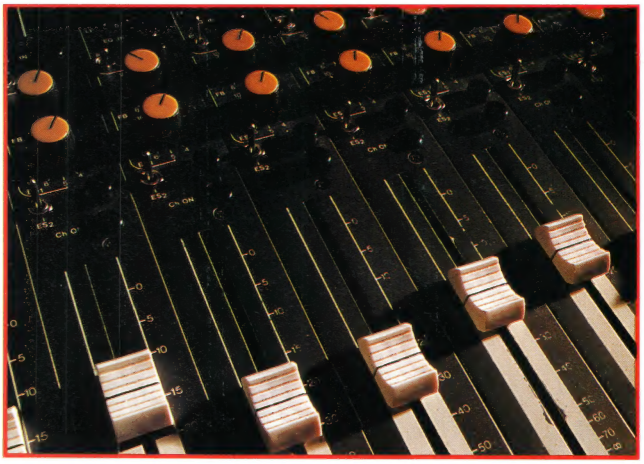
song — heard through headphones.

The usual order is drums, then bass guitar, guitar and keyboards, then lead vocals and backing vocals. Other instruments such as 'brass' (trumpets, trombones and saxophones) or 'strings' (violins, violas and cellos) or perhaps additional guitars or percussion may be added.

The vocals and acoustic instruments are usually recorded through a microphone. Microphones are transducers — they change sound signals into electrical signals. There are several different types. The one normally used for vocals, for example, is the moving coil. In it a coil of wire next to a magnet generates an electric current when moved by sound vibrations.

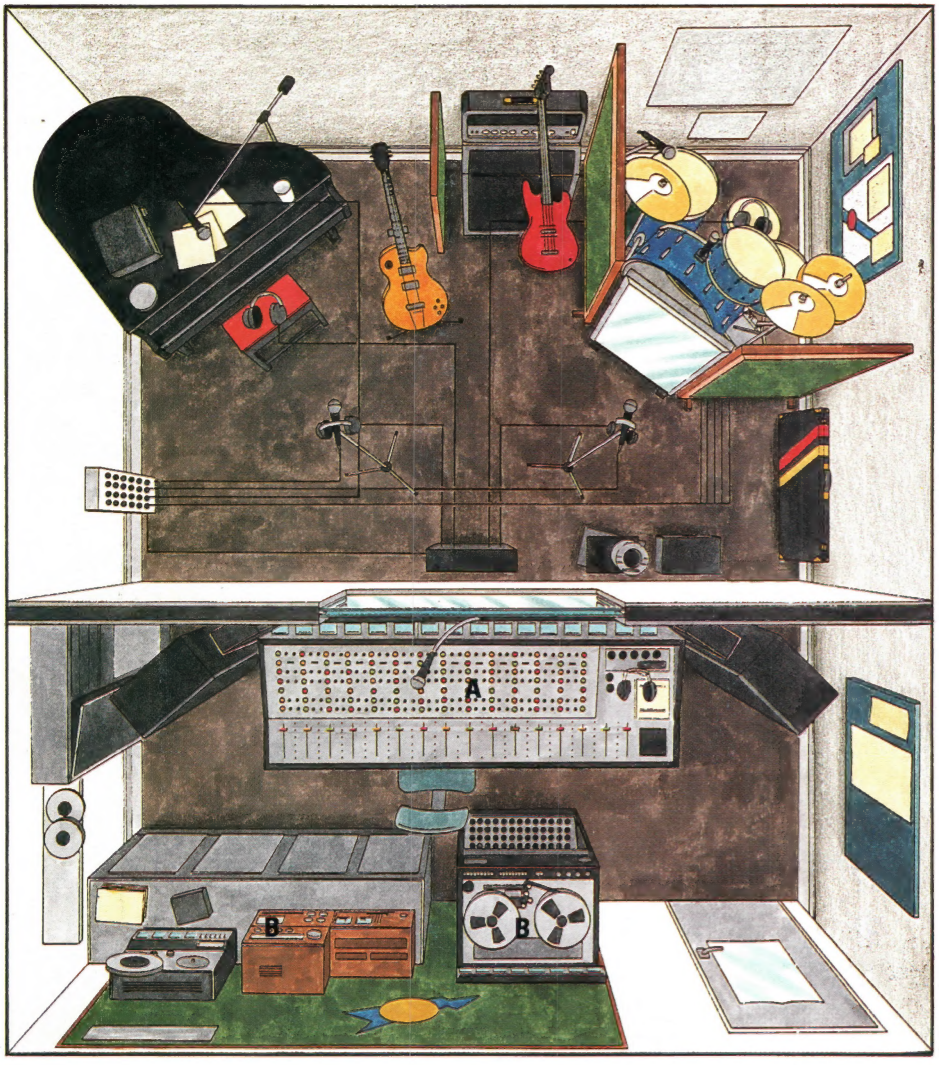
Alternatively, electric instruments, such as guitars and synthesizers, can be recorded directly into the mixing desk. This would be done if a 'clean' sound (one unaffected by the acoustical 'colouring' of the amplifier, loudspeaker or microphone) were required. If, on the other hand, a 'dirtier' sound were desired, electric instruments can be played through amplifiers and loudspeakers and the sound recorded by microphone.

***The fader controls** are basically tone controls, allowing the engineer a fine degree of adjustment.*



Ace

***The recording studio** is divided into the studio (top) where the musicians perform, and the control room (bottom) with the mixing desk (A) and recording equipment (B).*



Caroline Brodie

The individual sounds are recorded on magnetic tape. Professional recording tape is of a much higher quality than that found in most audio cassettes. It is also much wider — usually 25mm across compared with the 3.8mm of cassette tape, and 792 metres long compared with 121 metres for a C90 cassette. Whereas cassettes have two tracks (that is, two distinct recording/playback areas) — one on each side — professional tape has room for 24 tracks.

Time code track

Although there is room for two more tracks, the outside edges of the tape are not used for sound because of the danger of damage due to mishandling. On one edge, however, there is the SMPTE track. Named after the American Society of Motion Picture and Television Engineers who introduced it, 'simpty' is a universal time coding which simply records time, second by second.

Overdubbing

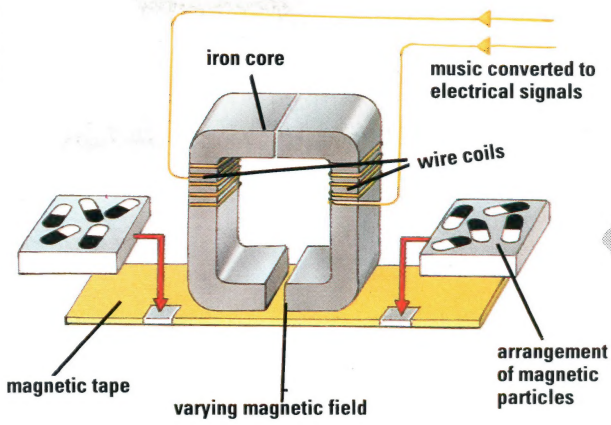
This means that the individual sound tracks can be synchronized, allowing extra tracks to be recorded later; also existing tracks can be corrected or improved. These techniques are known as overdubbing. SMPTE also allows two 24-track machines to be linked for a 48-track recording.

The various parts of the recording process may be carried out

directly, using analogue (non-digital) electronics. The recording process may also be done using digital, computer techniques. Digital music recording requires a huge memory, just five seconds of music takes up an enormous megabyte of memory – the equivalent of a large, 500-page novel.

Between the musicians and the tape recorder lies the most important part of the recording studio: the mixing desk. Each sound source – vocalist, guitar, drum, mike and so on – has a channel on the desk. The channel is the route through which the sound waves, translated into electrical impulses, travel on their way from sound source, through the mixing desk to tape.

John Houghton



The record head *on a tape recorder is an iron core, wrapped with coils of wire. Sound is converted into magnetic patterns. The variations in the magnetic field in the gap at the bottom of the core cause the magnetic particles coating the tape to vary their arrangement. These patterns are recorded permanently. The play head does the opposite job, reading the taped magnetic imprint and converting it back into sound.*

Production

Important though it is for the recording process, the mixing desk only really realises its potential once the recording is complete. The production takes place once all the sounds have been committed to tape. The mixing desk is the master control, allowing the technician to vary the volume and quality of each channel.

All musical sound is made up of many frequencies and the mixing desk allows any frequency to be boosted or cut back. A vocal that is too thin, for example, can be given an extra bassy quality by boosting its bass frequencies. A bass drum can be brought forward, a guitar brought up for a solo and so on.

Cutting a disc *involves mixing the multitrack tape (left) down on to a 2-track stereo master (right), then cutting a record blank.*

Mitsubishi Pro Audio Ltd

STUDIO JARGON

Bounce down – to combine tracks on the same recorder
Drop-in – re-record a portion to correct a mistake or improve that portion
Dubbing – copying one track or tape to another
Effects – devices such as echo, phasing, harmonizers that enhance the original recording
Graphic equalizer – a tone control system that displays the full range of audio frequencies and allows sections, such as the bass or treble, to be altered
Mix-down – to re-record multi-tracks on to a 6.35mm stereo master.
Overdubbing – adding tracks to an existing work
Reverb and echo – to repeat the original signal at slightly lower successive levels or different frequencies

Echoes

The producer can also add effects such as reverberation or digital delay. Reverberation, or reverb as it is called, is the addition of echo to enrich a sound. Digital delay can be used in several ways.

Paul Raymonde

Decca

***A digital mixer** with 16 channels. Sampling the audio signal at up to 50,000 times a second, a digital recorder converts the sound into on/off pulses.*

possibly on either side.

The most popular mixing desks are known as Solid State Logic (SSL) desks. These have built-in computers that can memorise every setting on the desk. So the producer can happily try many different combinations of sounds and technological effects.

If the sound is held up for a few thousandths of a second then replayed over itself many times, an effect called phasing is created in which the sound seems to sweep on and on. Or the sound can be held up longer to create the true echo effects required on a dub record. Digital delay can also produce an effect known as chorusing in which the frequency of a vocal is slightly altered and played back many times. This makes a single voice sound like a choir.

Once the sound has been equalised and effects added, the finished tracks must be mixed down on to a two-track master tape: one for the left and one for the right channel. The aim is for a full stereo image.

The stereo image

So drums, for example, may be spread across the image by putting the bass in the centre, the kick drums at either side and the cymbals left centre. Rhythm guitars may be balanced symmetrically around the centre with the lead vocals in the centre and harmony vocals

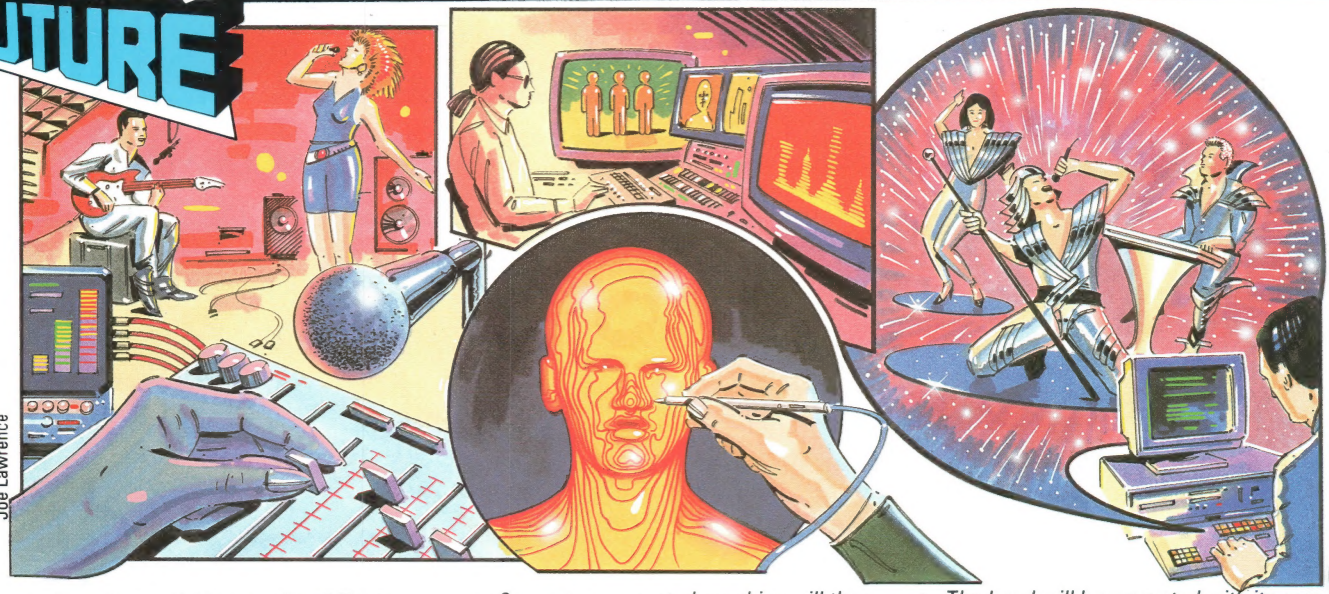
***Mobile recording** takes the control room and all its equipment to a concert hall.*

***Mobiles** usually have at least two multitrack machines so that the tape does not run out before the end.*

Fleetwood Mobile

INTO THE FUTURE

THE GHOST IN THE MACHINE

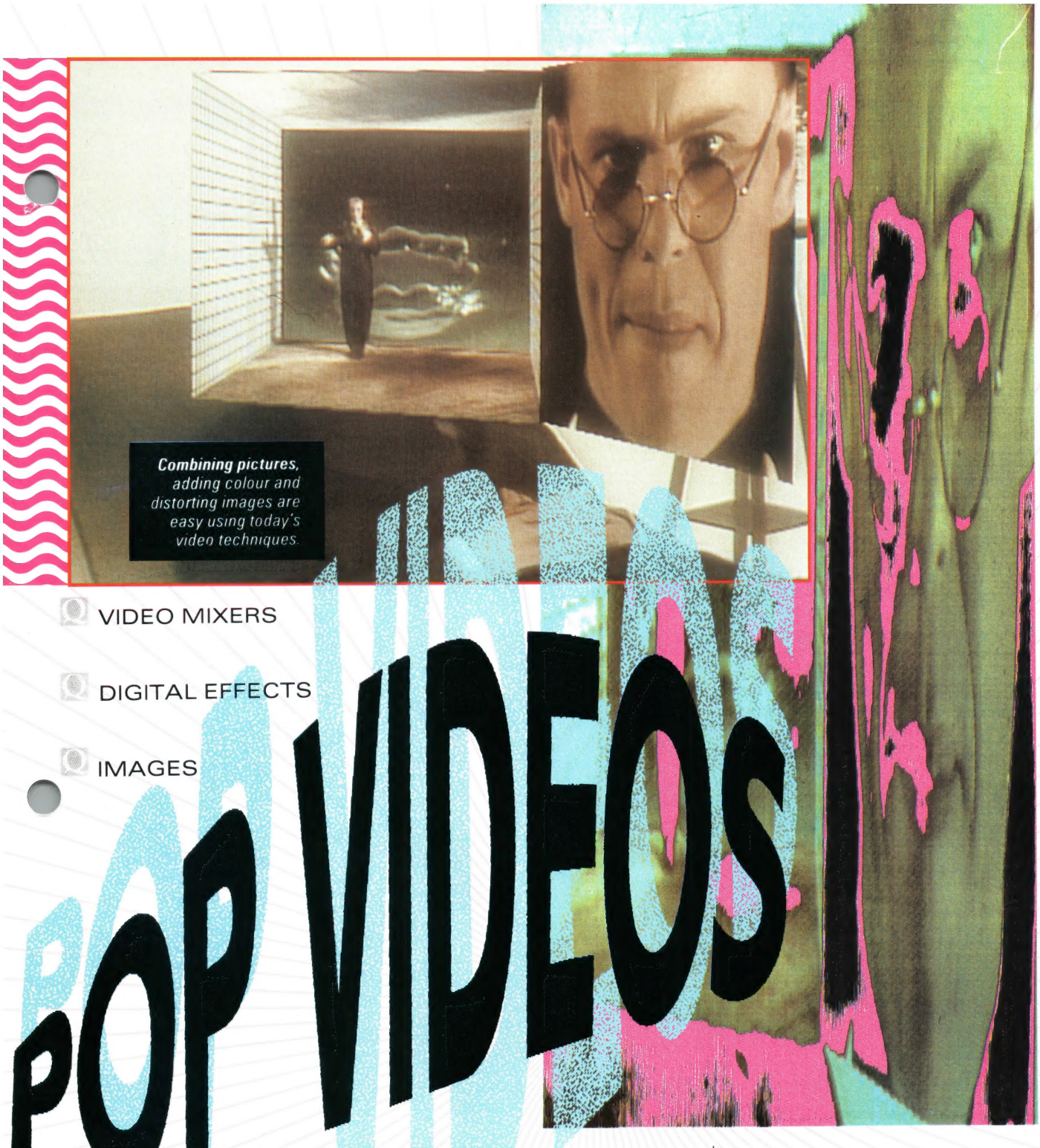


Joe Lawrence

▲ *Sampling techniques – the ability to create music from a single fragment of sound – will allow record producers to take a sample of guitar, piano, bass and vocal and create a completely new song.*

▲ *Computer-generated graphics will then be used to create the rock band of tomorrow, perfectly honed to match the new sound, able to work continuously for as long as required and perfectly behaved.*

▲ *The band will be promoted with its own pop videos and a whole, high-flying career launched through a ghostly creation that exists only in the mind of the creator and the memory of a computer.*



Combining pictures, adding colour and distorting images are easy using today's video techniques.

- VIDEO MIXERS
- DIGITAL EFFECTS
- IMAGES

POP VIDEOS

Picture Music International

VIRTUALLY EVERY HIT SONG HAS a video to go with it. But this is not just a short film of the group singing their latest record – computer-generated special effects, colour separation and sophisticated digital techniques are all part of the paintbox used to promote the product.

Producing the sound for a pop video is the easy part. It is usually taken from the studio recording of the song. This gives the director of the video an exact length of time to work to. It may also give him or her ideas for the content of the video, which he or she will discuss with the group. The song may also provide critical moments when the shot or scene has to be changed in time to the music. These will be worked into the shooting script or the story board.

A *shooting script* is a list of all the shots to be used, incorporating details of the action, camera angles and movements. A *story board* is a cartoon-strip version of the shooting script, giving an artist's impression of the main shots of each sequence.

Shooting

The original footage for a pop video can be shot on film or video. It does not have to be shot in the order dictated by the shooting script. The footage can be shot in any order and put together later.

The performers mime to a recording of the track, and the images are then processed and edited to fit the music so that sound and vision blend together perfectly. Next, any special effects are added. If any of the original footage is shot on film, it will be transferred to video so that special effects can be incorporated.

One of the most important techniques used in video making is chromakey, or colour separation overlay (CS). Chromakey is a technique for combining one image with another in one frame – it can be used to show a group against an unexpected background, for example. When you see a video with a

SPECIAL EFFECTS

A very important technique in pop video making is DVE – Digital Video Effects. It is a tool for manipulating video images. When you see an image suddenly shrink down and whizz around the screen, DVE has been used. Video signals are digitized and stored as digital information in a computer. They are then manipulated – by the system's own programs or by keypad and joystick. Each signal manipulation takes about 1/25th of a second. The result is an image that moves so fast that we see it as one flowing, seamless piece of hi-tech action.

Simon Critchley

Performing on the Moon *is simple: the artist is shot in front of a pure colour background, then the vision mixer fills in the colour with the background Moon shot.*

group flying through the air, or driving a car through a cartoon landscape, this is made possible by chromakey.

Pure colour

The first step in using chromakey to get these kind of effects is to record the two sequences which are to be combined. The images for the background sequence can be real, hand drawn cartoons or computer generated images. To make the foreground sequence, the group are videoed against a plain, pure colour – usually pure blue or pure green. The members of the band being filmed must not have any of the pure colour in their clothes.

A machine called a vision mixer is used to bring the band and background together. The two sequences are run simultaneously. The vision mixer analyses the one with the group in. Wherever it finds the pure colour, it replaces it with the background image. Elsewhere it leaves the foreground image. So the final sequence shows that band performing against the required background scenery.

Sinclair Stammers/SPL

Putting together a video *requires a bank of video machines – to play original footage, and record the result.*

Image manipulation by computer is another of the pop video maker's most important tools. Video images can be stored in a computer as digital data, then manipulated in the most extraordinary ways.

Stretch and spin

Images can be stretched, compressed, turned upside down, mirrored left to right, spun or put into false colours. On modern machines, images can be painted in – or painted out – at the editing stage, without having to reshoot the original footage.

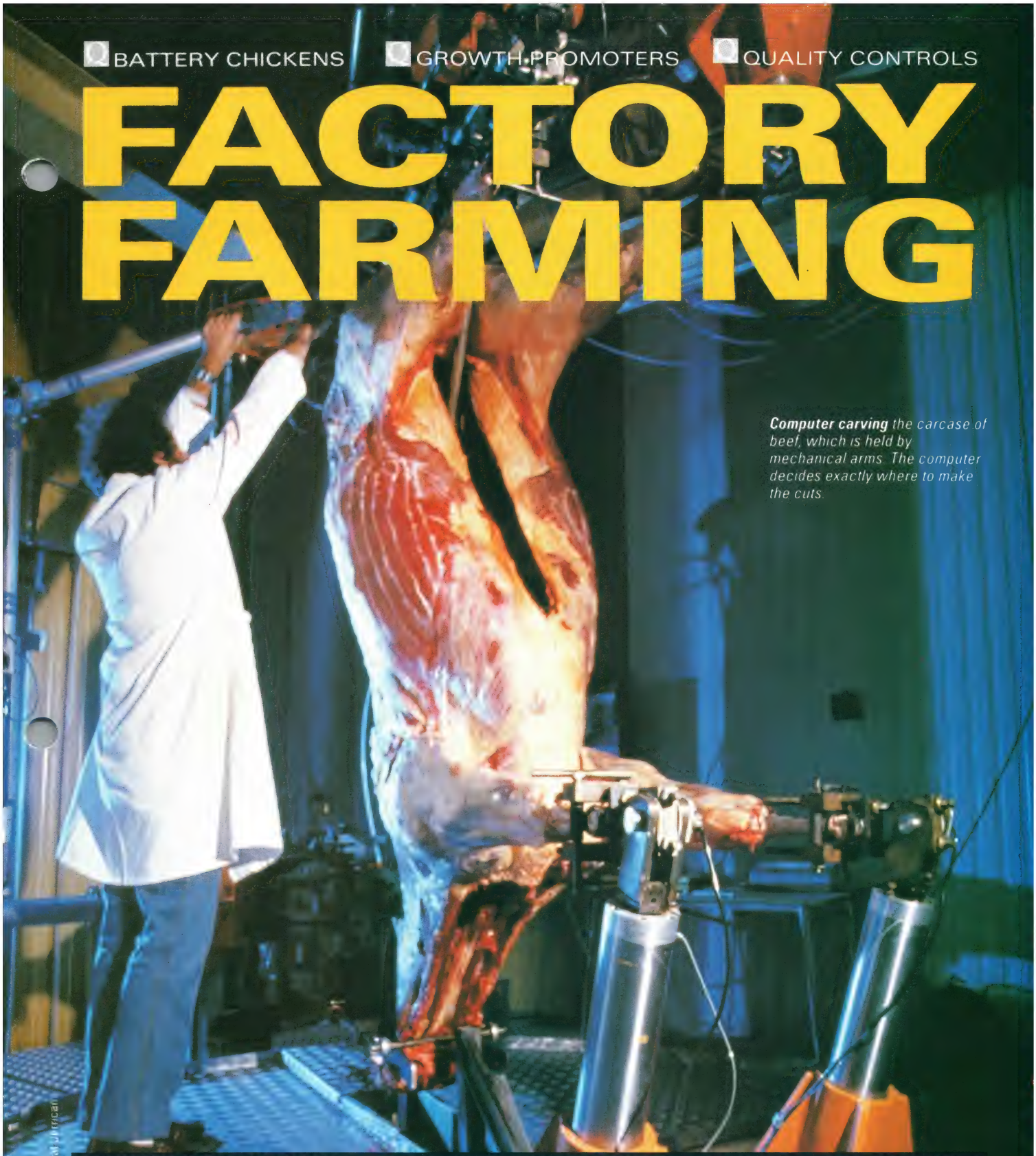
Manipulating video images in this way is extremely expensive – editing suites hire out at £200 an hour or more. Hundreds of thousands of pounds are spent on producing pop promo videos before they are distributed to the TV companies.

If the video is exciting enough to be shown on TV, it is worth millions of pounds in record sales to the record company and the group themselves.

Paul Raymonde

BATTERY CHICKENS | GROWTH-PROMOTERS | QUALITY CONTROLS

FACTORY FARMING



Computer carving *the carcase of beef, which is held by mechanical arms. The computer decides exactly where to make the cuts*

THE FOOD INDUSTRY TODAY starts on the farm. No longer do pigs grub about in the meadow or chickens peck in the farmyard. Rolling fields have, in many instances, given way to huge buildings.

In today's fast-moving world, the customer is looking for consistent quality in food, and a low price. The result is the supermarket, designed to sell vast quantities of food as quickly as possible. The message to the farmer is clear: the only way to satisfy the demand for vast amounts of cheap food is by intensive farming.

Cooped up

The modern farm has much in common with an industrial factory. Nearly all the eggs in Britain, for example, come from just 400 farms, where there are flocks of more than 20,000 birds in one building. The biggest chicken farm in the world, however, is in Ohio, USA, where five million hens lay nearly four million eggs every day. In these mass 'coops' the chickens get adequate food and water, are protected from foxes and other predators and are kept in hygienic conditions.

What is not known is whether these 'battery' chickens have enough room to move about, or whether they suffer stress or other problems. What is certain, of

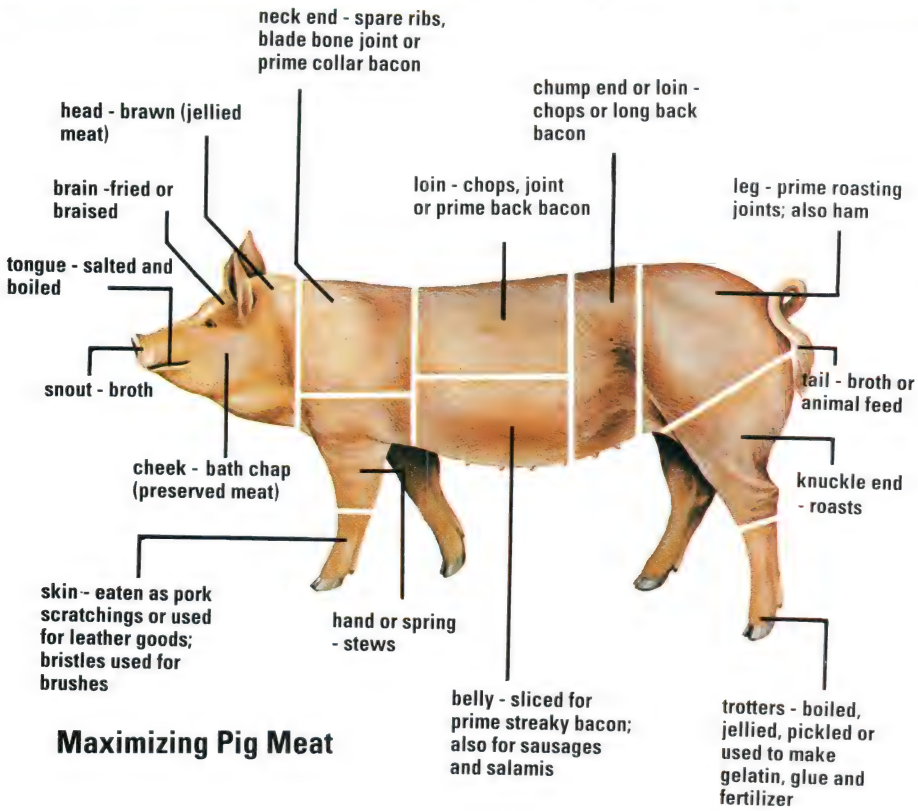
Daudier/Jerrican

Newborn piglets *are laboratory reared and kept completely clean in a germ-free environment.*

Genetic engineers *isolate a single gene that can promote growth. In this highly magnified shot, extra copies of a gene are introduced in a newly fertilized egg.*

Pigs are now bred *so that their meat is less fatty. Butchers divide the pig into various cuts, ensuring minimum waste. The heart and spleen are made into pâté, and the pancreas eaten (as sweetbreads) or used to make insulin. Blood and leftovers may be used for sausages.*

University of Adelaide



Maximizing Pig Meat

Elaine Keenan

course, is that if they were reared naturally the cost of their eggs would soar.

One reason for the mass rearing of chickens is that their meat is more popular today than ever. The average man or woman now eats ten times as much chicken as he or she did 50 years ago. Over the years, farmers have managed to rear ever-increasing numbers of chickens. As a result, the relative price of a chicken has fallen over the last 15 years by about 60 per cent.

A similar story applies to the pig. There are about 7 million farm pigs in Britain and some 60 million in the USA. Rapid advances in factory farming have ensured that most pigs lead a totally unnatural life.

Computer fed

A factory pig may start life as a result of artificial fertilization and have its birth accelerated. It is normal for piglets to be force-weaned in three weeks rather than the natural seven. They will then be monitored and fed by computer to bring them to the optimum slaughter weight – between 50 and 120 kg each – as rapidly as possible.

Pig in the middle

The factory pig cannot follow its natural inclination with regard to food. In one of the newest systems, each pig in a pen of 70 or 80 pigs wears a computerized ear tag. Food is provided at a special feeding stall that only one animal can enter at a time. The ear tag is detected by a sensor and depending on whether the pig has had its daily allowance or not, the pneumatically operated trough opens or stays closed. The factory pig simply cannot 'make a pig of itself' – which is just as well, as, if it had unlimited access to concentrated food, it would prob-

Just amazing!

HAPPY CHICKS

CHICKENS AND TURKEYS GAIN UP TO FOUR PER CENT MORE WEIGHT IF THEY HAVE 'WALLPAPER' MUSIC TO LISTEN TO AND BABIES' TOYS TO PLAY WITH.

Paul Raymonde

Weiss/Jerrican

***Battery hens** live out their lives in cramped conditions without ever seeing a farmyard. In recent years there has been a move away from battery farming towards free-range or barn farming. Newly hatched ducks (inset below) are herded into crates and sorted manually according to their sex.*

Compassion in World Farming

ably eat itself to death!

Such systems are thought to create stress in the animals. There is also concern about the level of artificial additives to pig feed, but much research needs to be done in this area.

Pig feed is normally brimming with added vitamins to compensate for the lack of sunlight and greenstuffs. Antibiotics are also added to prevent disease. Copper is used as a growth promoter – this has led to the poisoning of sheep after pig slurry was used as manure on grazing land. Hormone growth promoters are also used, despite fears that they may be passed on to humans.

Forced growth

Growth hormones are made by genetically engineered microbes that have had the gene from the animal inserted into them. They are either injected into the animal or given as an implant under the skin. Animals treated with growth hormones grow faster and can be taken to the market earlier, thus guaranteeing a better price.

The idea of accelerating growth (known as 'bringing on') is not unique to the farming of livestock. Crops, too, can be – and increasingly are – forced. One of the most common ways of doing this is to grow crops under transparent plastic strips about one to two metres wide. The plastic is perforated with anything from 100 to 500 tiny holes per square metre, so both sunlight and rainwater can pass through.

Underneath the plastic it is warm and humid, like a mini-greenhouse – just right for plant growth. The plastic does not even have to be removed and disposed of because it is photodegradable – designed to break down naturally in sunlight.

Early harvest

Covering means that crops can be sown earlier than usual, because although it may be a cool spring day above, under the plastic it is as warm as midsummer.

Many crops are now grown under plastic, including potatoes, carrots, sweetcorn and beet. Carrots can be harvested three weeks earlier if they are grown this way. This is extremely important for the farmer because, if he can get his produce to market before his rivals, he can get a better price.

Furthermore, some crops are more productive when grown under plastic. In one trial, there were 45,000 corn cobs over 30 cm long per hectare under plastic compared with just 17,200 in a normal field. Also, as with the carrots, they were ready for picking up to 10 days earlier, which again meant better market prices.

Off to market

After the farmer has done his job, the produce must be packed up and shipped off to market and then on to the shops. Technology has helped here, too.

Take apples, for example. Researchers at the University of Michigan, USA, have designed a tiny computer, shaped like the fruit, called an 'impact detector device'. It records

Farmers Weekly

***Perforated plastic strips** allow sun and rain to pass through, providing a sheltered environment for crops and encouraging higher yields.*

WHAT'S YOUR POISON?

For most victims of food poisoning, the worst consequences are vomiting, diarrhoea and a few days in bed. But for some, particularly the sick or elderly, food poisoning can be fatal. Poor handling, hygiene and storage, plus inadequate cooking or re-heating encourage unwanted bacteria. The most common are:

- **Salmonella** – bacteria thrive on warm meat and poultry; also found in eggs and egg products
- **Campylobacter** – often found in raw and poorly cooked food and unpasteurized milk. It is responsible for twice as many food-poisoning cases as salmonella
- **Staphylococcus aureus** – bacteria thrive on ham and bacon that other bugs find too salty
- **Listeria** – most likely to be found on 'chilled' pre-cooked convenience foods. The germ survives low temperatures and some boiling.

ORGANIC FARMING

All farming is – in a sense – organic because in chemistry this term means 'carbon-containing', and all molecules in living things are based on carbon. However, the modern meaning of organic is closer to 'natural'. It means farming without using artificial chemicals such as fertilizers, pesticides and herbicides. Farmers work 'within nature' using animal manures, garden compost and leaf moulds as fertilizers, and employing old-fashioned methods such as crop rotation, which prevents the soil becoming exhausted.

Phillip Hayson/Colorific!

The incubation room *in a plant cloning laboratory, Australia; here identical copies of one banana plant are produced.*

the intensity and frequency of any knocks and squeezes the skin receives. Using this computerized apple, it is possible to find out the best way for packing apples and which parts of their journey are the bumpiest. One interesting discovery is that most are damaged as they are put into bags after picking.

Nasty taste

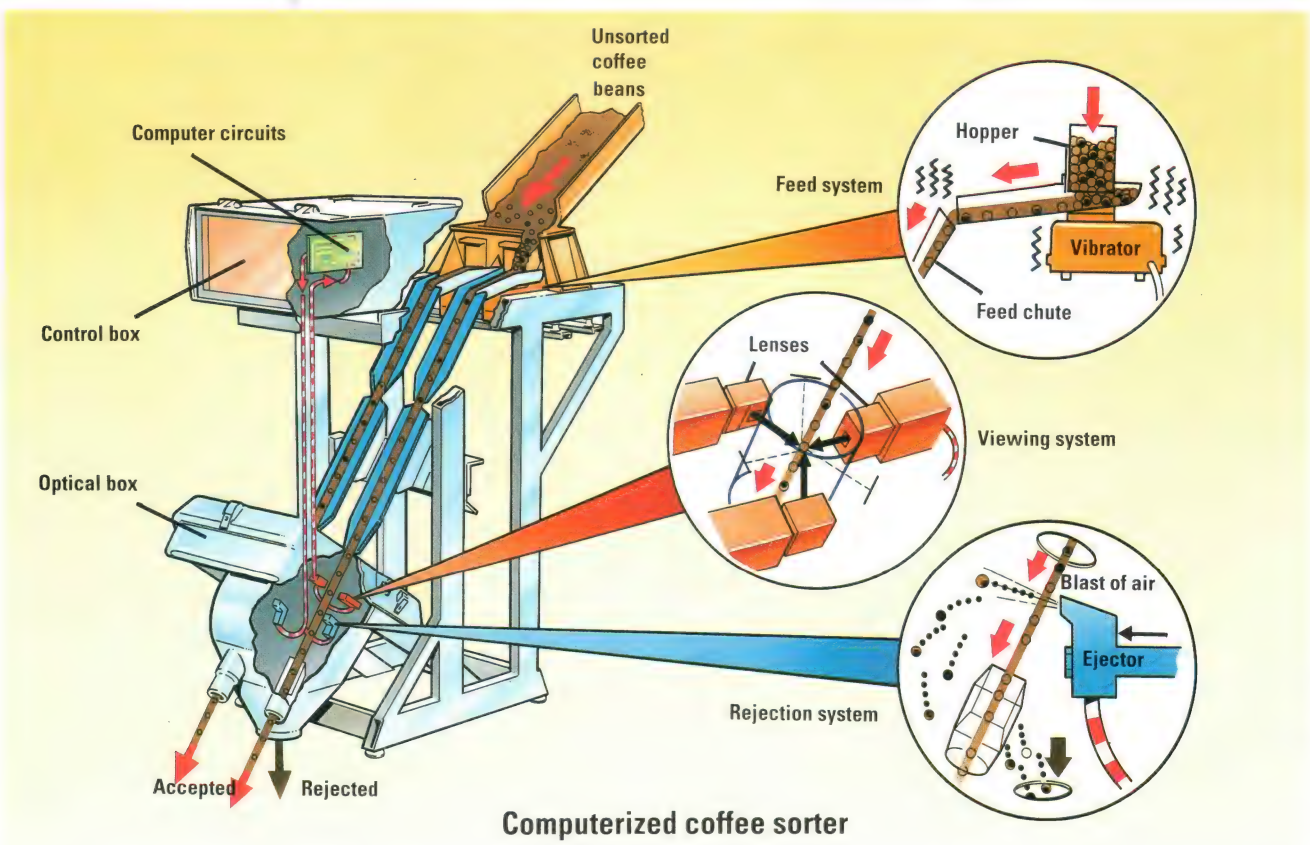
Another important task for the computer is detecting bad coffee beans. Rogue coffee beans, called 'stinkers', have a terrible flavour and, when ground up, can ruin a whole pack of coffee. Although a stinker looks perfectly normal, when it is viewed under ultraviolet light, it glows.

Colour sensors, called photocells, measure the type of light reflected from the coffee beans as they fall down a chute. These sorting machines work at incredible speeds, scanning the chute 1,200 times every second. Any bean that does not match the standard colour is blown into a reject box by a blast of air. Using this system, a single bean is inspected up to 20 times as it passes the 'magic eyes', ensuring it is fit to be ground into coffee.

Coffee beans *entering a computerized sorter pass an infrared light source. Any bean that glows is bad, so it is detected and blown out.*

US Department of Agriculture

An impact detector *shaped like an apple detects any bumps and bruises that the fruit receives while in transit.*



Computerized coffee sorter

Joe Lawrence

HYDROPONICS

PURIFYING WATER

ARTIFICIAL SUN

INDOOR FIELDS

Farmers Weekly

Riccardo Villarosa/Oxford Scientific Films

***Protected** from pests and weather in near perfect conditions, indoor yields can be 50 times those outside.*

***Without soil,** these plants flourish with their roots dipped directly into water containing all the nutrients they need.*

PLANT CROPS GROWING IN fields outdoors may seem romantic and peaceful. Corn waves in the wind and ripe apples glow on the orchard trees. But is outdoors the best place for farm plants to grow?

The waving corn could be attacked by rust fungus, which would ruin its growth – and the farmer's livelihood – while the wind that makes the corn wave is drying it out. Meanwhile, grubs could be boring into the ripe apples, tainting their flesh and spoiling them.

Greenhouses

If, instead, plants were grown indoors, they could be kept in almost ideal conditions, fed exactly the right amounts of water and nutrients. Pests and diseases could be kept out. With the right types of plants, farmers could harvest more of the plant material so less is wasted. The question is: is it worth it?

Building a huge greenhouse is expensive, and regulating the conditions such as temperature and humidity uses a great deal of energy. In addition, excluding all pests and diseases would be costly. Balanced against the expense is greater productivity and easier harvesting conditions. Also, crops could be grown in places where plants could otherwise never grow.

One way to make indoor fields more productive is to do away with soil altogether! This form of cultivation began when the soil-less Wake Island in the Pacific was made fertile by growing vegetables directly in water. Large tanks were filled with water and nutrients. Up to 40 kilograms of sweetcorn, tomatoes, lettuces, beans and marrows were harvested from each tank each week throughout the year!

Depending on the exact method used, growing plants without soil is known as nutriculture, aggregate culture, chemiculture, nutrient film culture – or by the more general term of hydroponics.

Nutrients

In soil-less culture, the plant grows in water that carries a carefully selected 'cocktail' of dissolved nutrients. To run at greatest efficiency, the farmer must also know exactly which nutrients his crop needs at each stage in its growth cycle, and

Simon Fraser/SPL

even from day to day depending on the general temperature and weather.

Computers can be programmed to open ventilators or pump the water round faster, depending on the conditions. The nutrient levels are monitored automatically and topped up when necessary.

Feeding solution

In the water culture system, shallow trays or racks hold a slow-moving stream of the 'feeding solution'. A wire frame a few centimetres above holds a supporting medium such as rockwool, plastic granules or rice husks. Young plants are placed in the supporting medium and their roots dangle into the water below, sucking up nutrients.

In other systems the plants are rooted in a growing medium such as clean sand or gravel, plastic granules or cinders. The feeding solution is either sprinkled onto the medium and trickles through, or is pumped up from below.

Viard/Jerrican

***This robot arm** is computer controlled to move the pots of flowers around so that they get equal lighting from all sides and grow straight.*

Many crops — including tomatoes, marrows, beetroots, beans, sweetcorn, lettuces, celery, peas, peppers and courgettes — are now grown using these soil-less systems. Researchers point to a long list of advantages when crops are raised without soil:

- You do not have to worry about building up the fertility of the soil, or exhausting it after several seasons.
- The technique is especially suitable in barren, rocky or sandy areas. Diseases hiding in the soil are also not a problem.
- Most seedlings grow into mature plants — outside the proportion that develop is far smaller.
- Indoor plants are clean, ready for the shops. Crops are almost entirely weed-free. They are easier to harvest and give bigger yields. More uniform in size, they are also easier to sort, pack and transport.

Water saving

Although hydroponic crops are grown in water, the system actually saves water. The water vapour given off the plants' leaves and stems (in a process called transpiration) is collected as condensation on the glass or plastic roofs and walls of the greenhouse and recycled back into the plants' water supply. Because it is collected by condensation, transpired water is remarkably pure — it has, in effect, been distilled.

Plants can also do without sunlight. In a pilot study, vegetables were grown hydroponically under controlled artificial light during winter in New York. The idea was to make them competitive with the vegetables brought year round, across country, by truck from Mexico or California.

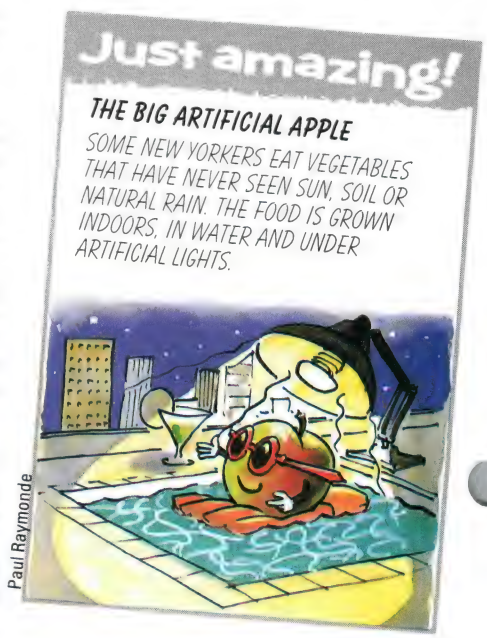
The yield per area was up to ten times bigger than the same crops grown in an ordinary greenhouse — and up to 50 times greater than out in the open field. The water was recycled too, and the system used only one-tenth the water that would be needed to irrigate crops grown outdoors.

***Banana trees** growing in Scotland! Under triple-glazed windows of the Hydroponcium (above) – the purpose-built hydroponics unit at Achiltibuie, West Ross – there is enough heat and light to grow such fruit as bananas, grapefruit and strawberries.*

In the future, grasses and similar plants could be grown on animal effluent — that is, liquid sewage. The water vapour they give off, when condensed, is pure enough to drink. So hydroponic installations could double up as water-purifying plants in arid areas.

Simon Fraser/SPL

Some scientists have suggested combining indoor plant-farming with fish-farming. The fishes' wastes enrich the water, providing additional nutrients for the plants to feed on.



Paul Raymonde

In modern surgery *patients rarely see this view – they are out cold before the surgeon starts work.*

SURGERY NOW

- BLOODLESS CUTS
- GOWNS AND GLOVES
- TRANSPLANTS

THE MORE BLOOD AND DIRT A surgeon got on his gown, the better he was, it was once believed. His eagerness to attack a limb that needed amputating was a measure of his experience – hence a surgeon's common nickname 'sawbones'.

In those days the patient had to be held down by three or four assistants – there were no anaesthetics. Hygiene was unheard of and many patients who survived the operation died afterwards from fever, due to infection of the operation wound.

Scrubbing up

The days of the sawbones are thankfully over. Patients are anaesthetized and operating theatres are scrupulously clean. Theatre staff wear sterilized gowns and perform meticulous 'scrubbing up' procedures before putting on surgical gloves so that their hands are sterile Many surgeons wear *two* pairs of thin, sterilized surgical gloves in case one becomes punctured. Special boots and masks are used to complete the sterile kit.

All the instruments are cleaned in the autoclave – a small oven that bathes them in super-heated steam – to kill off any bacteria that could infect the operation wound. All the other theatre equipment is disinfected prior to the operation, again

James Stevenson/SPL

***Sterilized surgical** instruments are laid out in a standard order before an operation begins. This set is designed for plastic surgery.*

Alexander Tsiaras/SPL

***Laser light** from a low-powered argon laser is directed by four fibre-optic waveguides to treat a cancerous tumour in a woman's throat.*

to ensure any germs are destroyed.

The operating theatre itself has special air filters to keep the air circulating and clean, removing any airborne bacteria. The patient is also disinfected before he or she is brought into this sterile environment. Before the initial cut is made, the area around the cut is given an extra clean just to be on the safe side. This total dedication to cleanliness is one of the greatest advances ever made in surgery.

New tools

Until recently, though, many of the other tools of the old 'sawbones' were used. The scalpels used to open up the patient, the retractors that held the cut open and bone saws were much the same as they had been for centuries. But now many new surgical techniques have been developed, taking advantage of new technology.

Welding retina

These days surgeons often use lasers. Torn bits of the retina (the light-sensitive part of the eye) can be 'tacked' back on again by firing a laser beam at the torn edges. This has the effect of 'welding' them back on to the rear of the eyeball. Even a detached retina can be reattached by accurate firing of a precisely focussed laser beam.

A serious eye disease called glaucoma (an increase in the pressure within the eyeball) can be treated using specialized lasers. These lasers actually punch holes in tissue rather than just melting it. By shining laser light through the cornea, a surgeon can relieve the pressure without opening the eye with a knife.

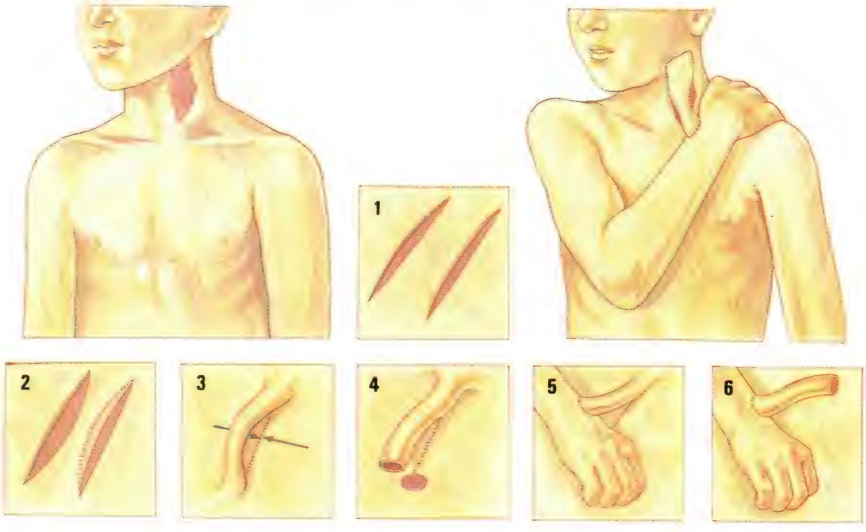
Burning tumours

Laser beams are also used in treating tumours (a tumour is an overgrowth of abnormal cells). Tumours can be cut out, but this may be dangerous to surrounding structures. If a laser is used instead of a scalpel, the operation can be carried out more accurately, burning away only the tumour and leaving the healthy tissue undamaged. An added advantage is that the laser produces a bloodless cut. Its heating, burning effect welds the wounds, as it cuts away the diseased tissue.

Without cuts

These days surgeons avoid cutting open a patient, where possible. Instead they use an instrument called an endoscope. This consists of a flexible

***Free-flap surgery** is used to repair damage to visible areas like the face by taking tissue from other, less visible parts of the body. Here, a flap of flesh is lifted from the patient's stomach **(1 + 2)** and the two sides of the wound are sewn together **(3)**. The flap of flesh is then detached at one end and formed into a tube **(4)**. The cut end of the flap is sewn on to the wrist to ensure good blood supply **(5)**. Next the other end is detached from the stomach **(6)** and the tube is sewn on to the wound.*



John Houghton

IMAGE CHANGING

Gamma/Frank Spooner Pictures

Gamma/Frank Spooner Pictures

Cosmetic surgery can radically alter the way you look. Michael Jackson has had his lips narrowed, the shape of his chin altered, silicon implants put in his cheeks and his nose trimmed down several times. He has also had his skin bleached, the shape of his eyes altered, eyeliner permanently tattooed around his eyes and his hair permed.

Cosmetic surgeons also commonly remove unsightly birthmarks, enlarge women's breasts by implanting bags of silicone and remove wrinkles by tightening the skin in a so-called face-lift. Silicone implants are also used to give extra fullness to lips and earlobes. Thighs can be reduced in size by sucking out the extra fat, using a technique called liposuction.

ZEFA

The 'nose job' *trimming or straightening a nose is one of the most common cosmetic operations. The bridge of the nose is broken and reshaped from the inside*

tube carrying opticle fibre cables and other facilities, including a suction tube and forceps.

A fibre-optic cable has the advantage of being able to carry light around corners, so the surgeon can see right inside the patient's stomach, for example, without cutting the patient open. The cable can be inserted into the mouth and down the throat. If the operator sees something that could be abnormal, the forceps can cut away a sample for analysis.

The endoscope can be connected to a video and television monitor so that a team of specialists can view the abnormal area. If surgery is needed, laser light can be chanelled into the area and the operation performed without ever having to cut open the patient.

Microsurgery

Surgery has now progressed to the point of being able to replace limbs that have been cut off in an accident. Sewing back an arm or a leg is relatively easy, but making the limb work again needs microsurgical skills. These incredibly delicate techniques are needed to reconnect nerves and tiny vessels so that life, feeling and control of the limb can be restored.

If a severed limb is to stay alive it must be kept cool so that it remains in 'suspended animation'. All the arteries, veins and nerves on the remaining stump must be identified so they can be re-attached to the correct ones on the severed limb. The bone must be wired together and every tiny nerve and vessel sewn up. Lastly, the muscles and tendons have to be sewn together and the skin closed.

If all the vessels are reconnected correctly, the limb will flush pink. After 6–8 weeks, the nerves usually heal and work again, and feeling returns to the re-attached limb.

Brain breakdown

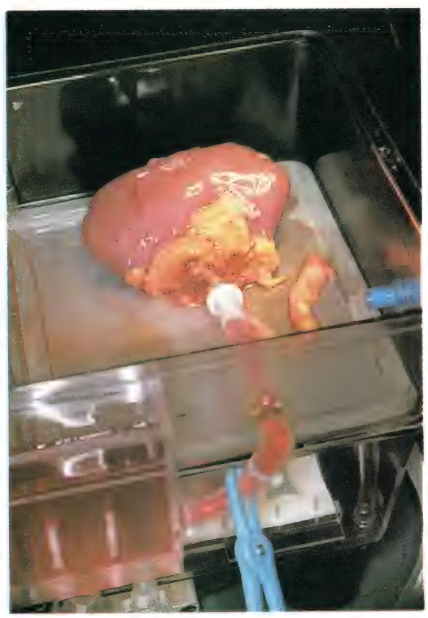
Microsurgery is also being used to treat certain brain disorders. In treating a debilitating condition called Parkinson's disease, a totally new — and controversial — technique has been developed.

In Parkinson's disease, a certain brain chemical appears to run out. The chemical in question is called dopamine. (Without it, uncontrolled muscle twitching occurs.) The tiny area of the brain which produces it, inexplicably, stops working.

Embryo drug

The conventional treatment for Parkinson's disease involves the patient taking artificial dopamine (L-dopa) for the rest of their life. But recent research has developed a way of replacing lost dopamine.

If tissue from a human embryo is transplanted into the area of the brain that is low in dopamine, the patient's symptoms may be relieved. The symptoms don't return



Hank Morgan/Rainbow

Human kidneys *have to be kept alive while they are being transplanted. This unit pumps blood through the kidney to keep it functioning.*

Just amazing!

CHOPS AND CHANGES

IRISHMAN WILLIAM MCILROY HAD MORE THAN 400 OPERATIONS IN 100 DIFFERENT HOSPITALS DURING HIS LIFETIME, COSTING THE BRITISH NATIONAL HEALTH SERVICE MORE THAN £2.5 MILLION.

Paul Raymonde

The Telegraph Colour Library

The Telegraph Colour Library

***Eye operations** are incredibly delicate and have to be performed using a microscope. Here, the lens is being removed – because it has become cloudy – and being replaced by a new plastic one which will restore the patient's sight.*

because the embryo's dopamine-producing cells take over production of the chemical. Transplanting the embryo cells in just the right place involves new microsurgical techniques.

Another area of enormous surgical advancement is organ transplants. But there are several complications involved in organ transplantation. The most important is tissue rejection. This occurs when the tissue of the recipient is not exactly the same as the tissue from the donor.

The recipient's immune system does not recognize the foreign tissue and treats it as if it were an invader. So his or her body attacks the new organ and rejection occurs. One way of overcoming this problem is to give the patient antirejection drugs such as cyclosporin that prevent the immune system from doing its job. The problem is that the body is then open to attack from other diseases as its defences are low.

Matching tissues

Another way is to 'tissue type' the donor and recipient very carefully before the operation, to make sure that both are compatible. This is done by taking blood samples and checking them for similar genetic material. The best chance of finding an exact tissue type is with a close relative who has the same genetic background. Once the tissue type has been matched, the operation can proceed.

Heart transplant

If a heart is being transplanted, the patient will have to be connected to a heart-lung machine. This takes over the function of both the heart and the lungs so that the heart can be removed and replaced without cutting off the circulation and killing the patient.

Kidneys can be transplanted, so freeing the patient from a kidney machine. The liver, too, has been successfully transplanted, sometimes with the bowel. This is particularly important as no artificial liver machine has yet been developed.

Spare flesh

Following a severe accident, the victim may need plastic surgery. A face may need to be rebuilt. But where is the spare flesh to reconstruct the damaged area to come from? The easiest way to avoid the problems of rejection is to take it from the patient's own body.

The spare tissue is usually taken from another healthy area of the person's body in a technique known as free-flap surgery.

Saving face

To rebuild a face after accident or surgery, a flap of flesh may be partially cut away from the chest, arm or stomach. Once the 'free-flap' of flesh is growing well and the wound where it was severed from the body is healing nicely, the free-flap is moved to the area of the face where it is needed. When the full thickness of skin is grafted on in this way, scarring, and shrinking of the graft, is minimalized.

Gamma/Frank Spooner Pictures

***To treat brain tumours,** you first need a sample. A local anaesthetic is given, then a 3 mm puncture is made and a tiny sample extracted with a needle.*

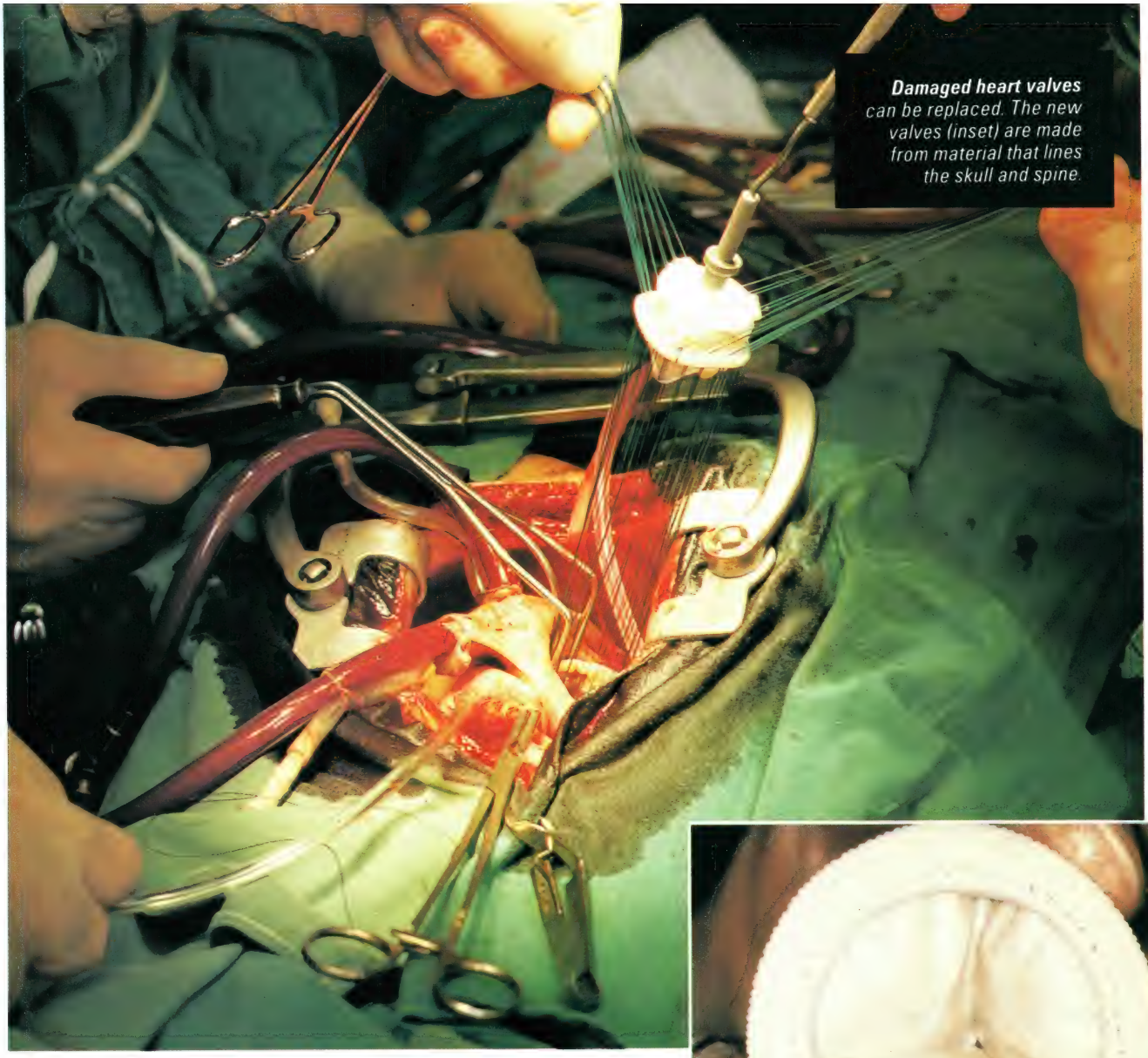
AS GOOD AS NEW

Gamma/Frank Spooner Pictures

Gamma/Frank Spooner Pictures

Extraordinary operations are now possible. If you have lost an arm or a leg, it can be sewn back using microsurgery techniques. Ten-year-old Timmie Mathias (top) had his head sewn back after a road accident. The strong ligaments connecting his spine and his skull were snapped when he was hit by a lorry and dragged along in its wheels. After a six-hour operation he is now almost as good as new.

Ten-year-old Meng Xin (above right) was run over by a train which destroyed her left forearm and thigh. Her hand was usable, however, and in an 18-hour operation, her left shin-bone was used to reconstruct her arm to give her use of both hands.



Damaged heart valves can be replaced. The new valves (inset) are made from material that lines the skull and spine.

Martin Dohrn/SPL

David Leah/SPL

MEDICAL MIRACLES

- RESTORING SIGHT
- HEART PACEMAKERS
- NEW JOINTS

NOT SO LONG AGO, IF YOU went blind, became deaf or lost a limb, nothing could be done. But now, medical science has developed new techniques to treat almost every condition – even those once thought incurable.

It is even now possible to replace the lens of a human eye. Cataracts and diabetes can cloud lenses and patients used to be told that nothing could be done for them. But now new materials and techniques can restore sight. The operation involves opening up the clear part in the middle of the eye – the cornea – using a microscope. The old lens is removed and an artificial one implanted.

Total deafness was once untreatable and the patient just had to live with it. But now, with modern electronics it is possible to implant a microelectrode directly into the inner ear. The electrode is activated by a hearing aid. This hearing implant is still in the early stages of development and is limited to use in certain types of deafness. For example, people with hearing nerve damage cannot use this method. But the potential of this new technique is enormous.

Pacemakers

Small electric shocks can be used to stimulate a diseased heart. Normally the heart has its own pacemaker which produces an electrical impulse along special conducting fibres. When this wave of electrical excitement spreads across the heart tissue, it contracts, pumping the blood around the body.

Some diseases interfere with the conducting tissue and the heart will not contract correctly. The treatment is to implant an artificial pacemaker, to take over the job of the

Dan McCoy/Rainbow

Complete artificial hearts have been implanted. But it is impossible to make a pump as durable as the original.

natural one, restoring normal heart function. A small electrical unit is installed inside the patient's chest cavity with electrodes connected to the heart itself.

Heart attack

Electrical stimulation is also used in emergency cases when the heart stops. When a heart attack occurs, the heart must be restarted within three to four minutes – otherwise brain damage is likely to occur due to lack of oxygen.

A machine called a cardiac defibrillator is used to restart the heart. When a heart attack occurs, the heart muscles go into a state of flutter – or fibrillation. The jolt of electricity from the defibrillator will stop this flutter and restart the heart.

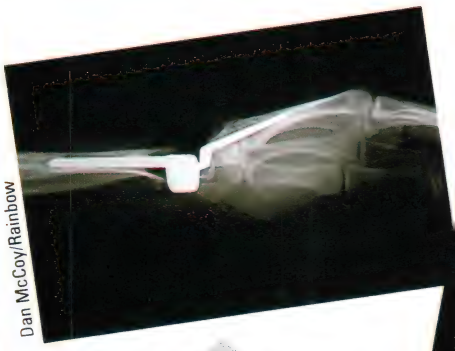
Diabetics suffer from a malfunction of the pancreas and many have to inject themselves with a substance called insulin at least once a day to control their blood sugar level. But devices are now available that deliver the vital insulin around the clock in a continuous slow stream via a small pump.

These new insulin-infusion devices are worn in a pouch on the belt. They are connected to a vein via a special needle that is attached to a tube which plugs into the machine.

New joints

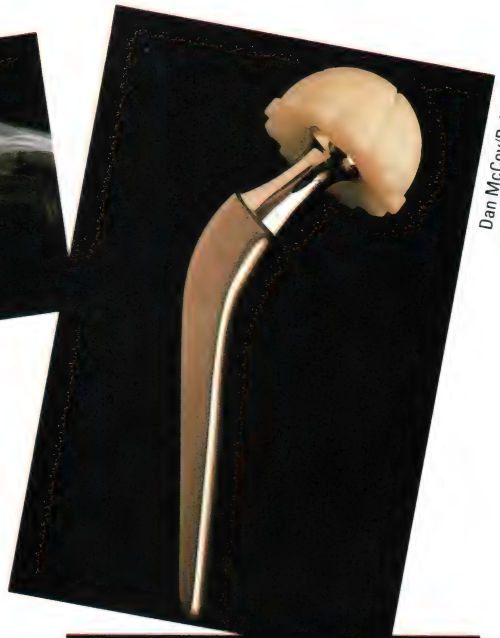
When the joints in our bodies wear out, they can now be replaced with artificial ones. The surgeon cuts out the damaged joint and drills out the shaft of the bone. He fills this shaft with a special type of 'cement'. The artificial joint is positioned with its anchoring pin down in the shaft.

Once the cement is set and the artificial joint is firmly fixed into position, full movement is restored. Artificial joints can last for over 15 years.



Dan McCoy/Rainbow

An artificial wrist joint in position, seen on an X-ray. The new joint allows the patient to have full movement of the wrist.



Dan McCoy/Rainbow

A man-made hip joint is made largely from stainless steel for strength, it has a plastic socket to allow smooth movement.

Dan McCoy/Rainbow

Stainless steel and plastic are used for a new knee. This combination 'self-lubricates' the joint.

ZEFA

Computer control is coming to artificial limbs. Nerve impulses in the remaining muscle tissues are detected and interpreted by the computer that, in turn, controls the movement of the artificial limb. Wearers sometimes say that it feels uncannily like their own limb.

Just amazing!

A HEARTY MEAL

NOVELIST THOMAS HARDY'S HEART WAS EATEN BY A CAT! IN A DISPUTE OVER THE DISPOSAL OF HIS BODY, HIS HEART WAS TO BE BURIED SEPARATELY. LEFT MOMENTARILY ON A KITCHEN TABLE, IT WAS GRABBED BY HIS SISTER'S CAT.

Paul Raymonde

- SCANNERS
- MEDICAL LASERS
- DIALYSIS MACHINES

LIFE-SAVING MACHINES

ADVANCES IN PHYSICS AND engineering have helped modern medicine enormously, especially with machines for diagnosing and treating illness and injury. The first example of this 'new technology' was the X-ray machine.

X-rays were discovered by Wilhelm Roentgen in 1895, and so named because their nature was unknown. They pass through soft body tissues, but are absorbed by denser material. So when a beam of X-rays is passed through the body and on to a photographic plate, solid objects such as bone show up as negative images.

Ways with X-rays

Not only bones are X-rayed. By passing special dye-like substances into veins and arteries, the course and diameter of these structures can be determined. This is very important in disorders of the blood system. The same dye-like substance can be injected into joints to investigate their condition.

Since X-rays are blocked by metal objects, they are used to assess the results of hip replacement operations, because an artificial hip is made out of metal, normally titanium. They are also used to locate objects such as coins swallowed by mistake!

Imaging techniques

But X-rays are still restricted in their usage. An alternative technique for seeing inside the body is called Magnetic Resonance Imaging (MRI). The advantages of MRI are that it

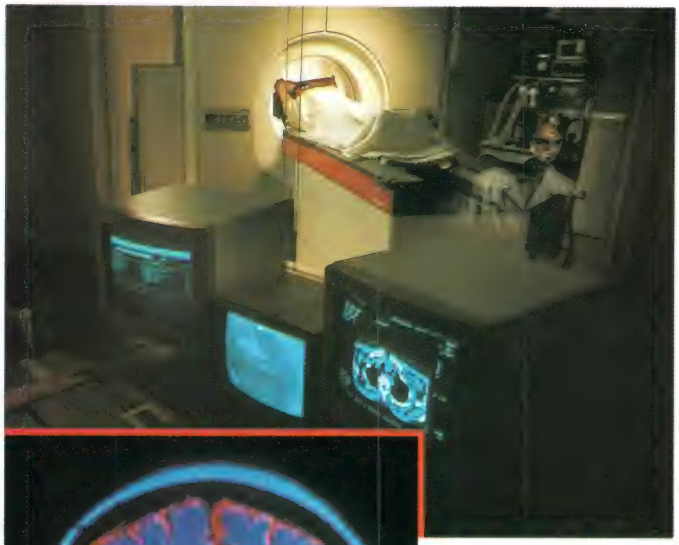
Philippe Plailly SPL

***Positron Emission Tomography** (PET) examines the brain using radioactive substances, which must be inhaled through a mask. It gives a highly detailed image.*

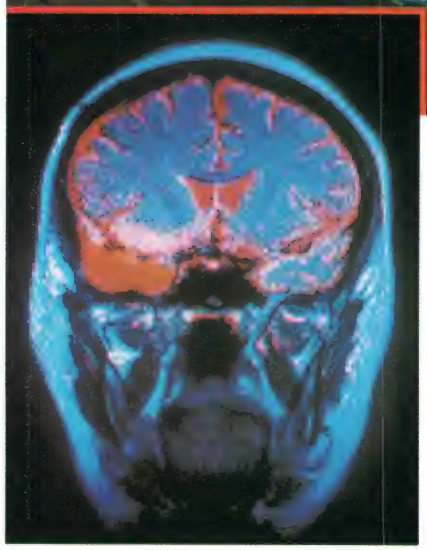
can produce clear pictures of soft tissues as well as bone, and there is no harmful radiation as it is based on magnetism and radio waves.

The MRI machine works by surrounding the patient with a powerful magnetic field. Soft body tissues contain many hydrogen atoms, which react to magnetism. When the protons in these hydrogen atoms are subject to a magnetic field, they start to spin in different directions – they are said to spin out of phase. A microwave generator is used to send out alternating radio frequencies, which make the protons 'flip' in and out of different energy levels. This in turn produces a detectable signal from the protons, which reflects the density of body tissue. When these complex signals are fed into a computer, a picture of the different densities can be made, producing a very clear and accurate image of the human body in cross-section.

Surgical gas lasers *are used for delicate operations. The laser beam is produced in a gas-filled tube. An electric current is used to 'excite' the gases, producing a stream of photons, which are then directed by mirrors out of the laser.*

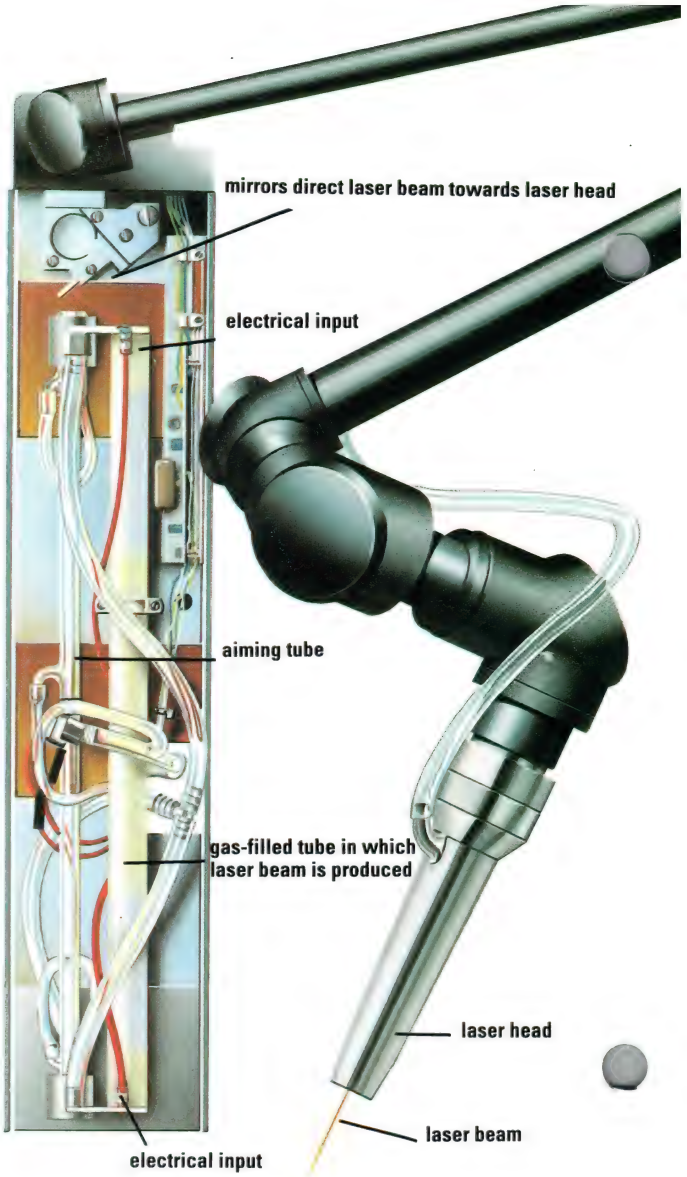


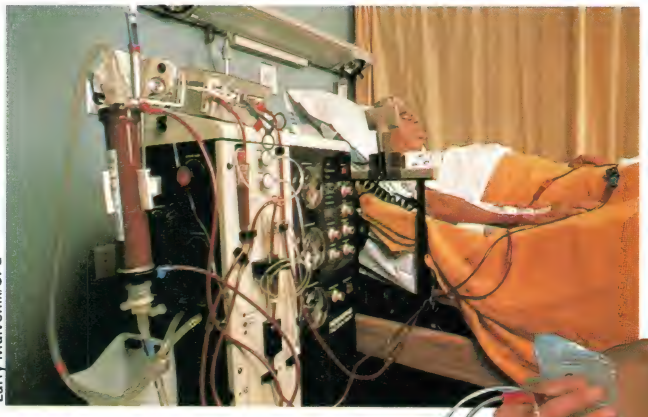
Tony Stone Photo Library, London



Dan McCoy/Rainbow

A brain scan *is produced by Magnetic Resonance Imaging. The patient is placed inside a huge drum and surrounded by a magnetic field. When radio waves are applied, a detailed colour image shows up on the computer screens (above).*





Larry Mulvehill/SPL

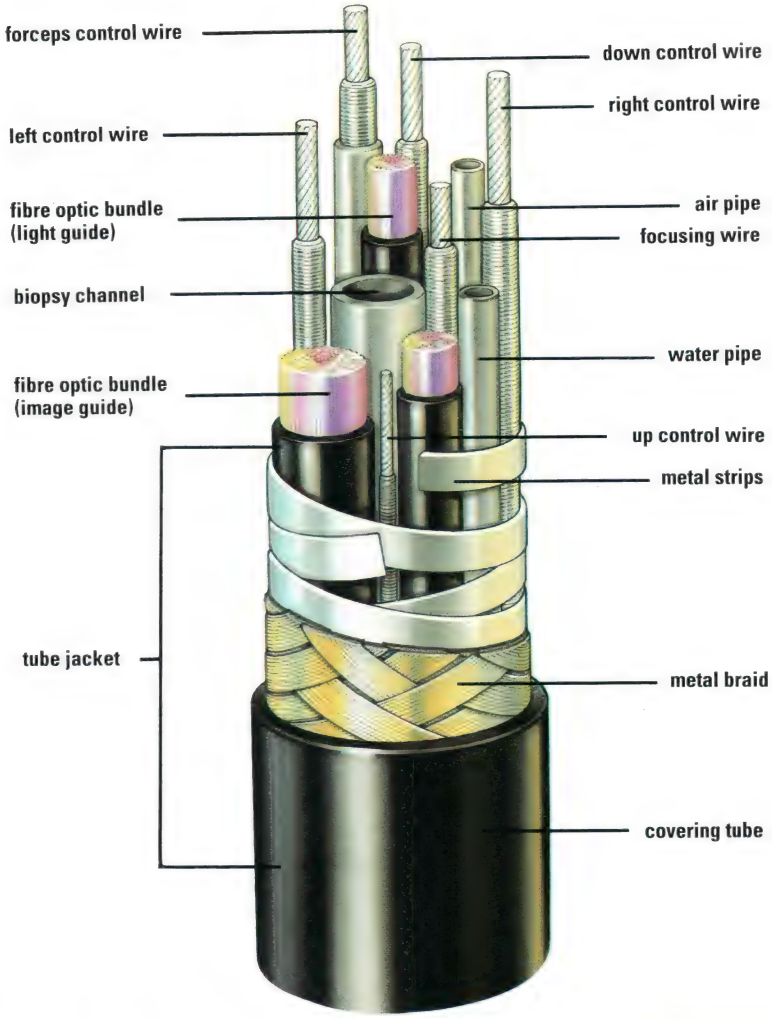
Kidney failure *is no longer fatal, thanks to kidney dialysis machines – but these are large and expensive. In a newer method, (below) fluid is pumped into an abdominal cavity to cleanse the blood.*

St Bartholomew's Hospital, London/SPL

CT scanners

Another type of scanner is the computerized tomography (CT) scanner. The machine works by calculating how much X-ray energy is needed to pass through the area being scanned, called the voxel. From this data, the machine produces picture elements (called pixels) on a television screen, just like on a home computer. Dense structures such as bone appear white and air appears black, with the different organs coming out as shades of grey. The images are of better quality than X-rays, but not as good as the MRI pictures.

The newest imaging machine is called Positron Emission Tomography (PET). It works in a similar way to the CT scanner but the X-rays are released from a short-lived piece of radioactive material called a radionuclide. This very specialized piece of equipment is mainly used



John Houghton

Endoscopes *are used to explore inside the body and even perform surgery by remote control. The flexibility of the tube allows surgeons to 'see round corners'. The shaft contains fibre-optic bundles to illuminate and view the area to be explored, wires to control the instruments at the tip and pipes to carry air and water if necessary.*

to examine the brain.

We now not only have the technology to diagnose many diseases, we also have machines to treat them efficiently.

Laser treatment

Delicate operations can be carried out by medical laser (Light Amplification by Stimulated Emission of Radiation). There are many different types, but the principle behind them is the same. They all need an active medium (normally a gas or a solid), and also an excitement source to 'pump' power into the medium.

For example, the Helium-Neon (He-Ne) laser works by exciting a mixture of Helium and Neon inside a gas tube. The atoms become excited by electrical energy and 'jump' to a higher energy level. This is then released as a photon (packet) of light radiation. The photons collect in the tube and are directed out by mirrors through an aperture. This stream of photons is the laser beam.

Invisible cuts

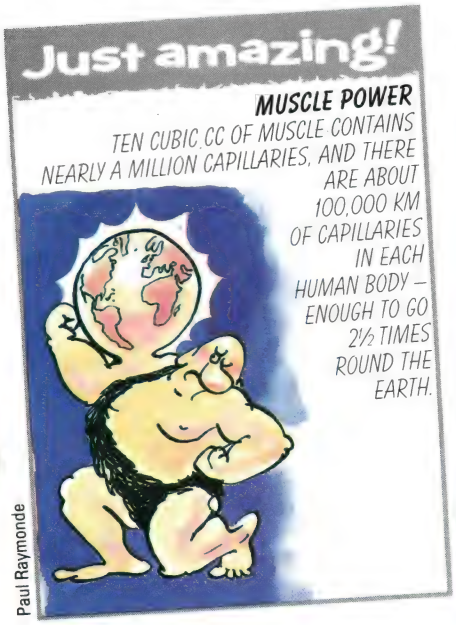
The He-Ne and Carbon dioxide (CO_2) lasers are gas-based, while the mid-power Gallium Aluminium Arsenide (GaAlAs) diode laser uses a solid medium to generate photons. The surgical CO_2 laser can remove tumours (growths), and open or seal blood vessels. One great advantage is that it can seal tissue as it cuts, therefore minimizing the bleeding during surgery. It is also used to treat damage to the retina of the eye (see 'Surgery Now', New Technology, pages 131–134). The mid-power He-Ne and GaAlAs lasers may be used to treat certain types of muscle and ligament injuries, as well as a wide variety of skin diseases.

Medical machines, such as the kidney dialysis machine, can now take over the functions of human organs. In patients with kidney disease, the normal filtering function of the kidney is lost and toxic waste products build up in the patient's blood, which can lead to death.

Martin Dohrn/SPL

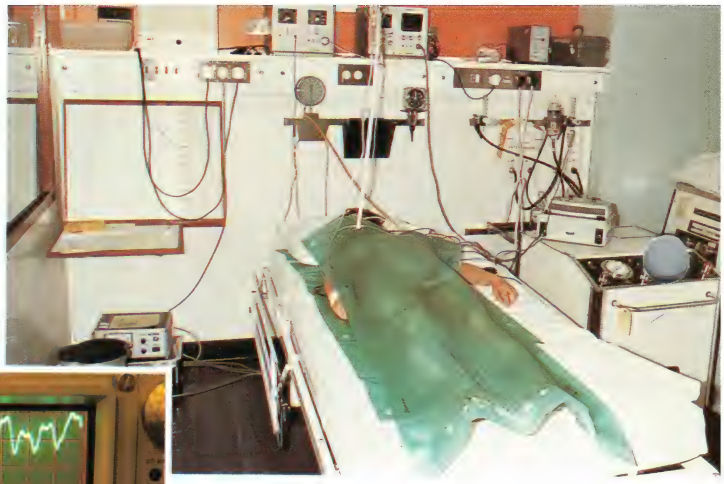
Digital Vascular Imaging (DVI) *helps surgeons see the blood vessels they are operating on – and allows the patient to watch his own operation. The artery is injected with dye and X-rayed, so that it shows up clearly on the screen. The purple lines (below) are blood vessels.*

Dan McCoy/Rainbow



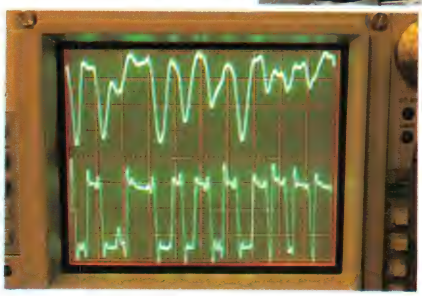
Paul Raymonde

When kidney failure is diagnosed, the machine will keep the patient alive until a replacement kidney is found. Many patients live quite normally with regular trips to this 'dialysis' machine, which separates waste products from the blood. The machine is linked via a plastic tube to the radial artery in the patient's wrist. Blood passes along this tube to enter a part of the machine where the waste products are filtered out across a semi-permeable membrane. The 'cleansed' blood is then pumped back into the patient through a vein in the wrist. But if both kidneys are not working, the patient may have to undergo this process of dialysis by visiting a kidney machine two or three times a week. This is expensive and time-consuming, both for the patient and the hospital.



Dan McCoy/Rainbow

Life-support systems *can keep patients alive for years after brain death occurs. An electro-encephalograph (below) monitors any remaining activity and triggers the reflex responsible for breathing.*



Tony Stone Photo Library, London

The heart and lung machine *takes over the functions of those two organs during heart transplants, keeping blood flowing around the body.*

Biophoto Associates/SPL

Portable dialysis

So scientists have devised a method of filling the peritoneal cavity in the abdomen with special dialysis fluid. The natural membranes of this cavity act like the semi-permeable membrane inside the kidney machine. They allow waste products to diffuse into the fluid, which is drained off after two hours, while the cleansed blood runs its natural course. This 'portable' dialysis machine is much cheaper and simpler than a kidney machine.

Another life-saving machine is the 'heart-lung machine' used during heart transplant operations. When the heart is removed, the blood circulation must be maintained or the brain will quickly die from oxygen starvation. The kidneys also need plenty of blood to keep them functioning correctly. So a heart-lung machine takes over the functions of the lungs and heart.

Capillary action

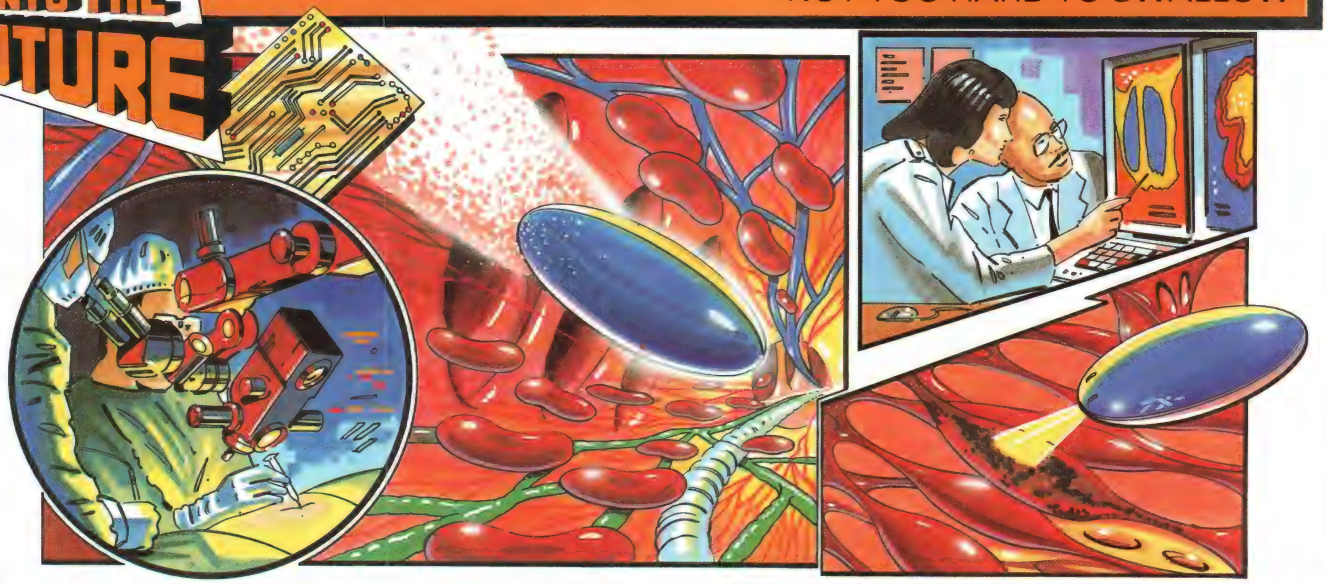
The lungs contain blood vessels, called capillaries, with very thin walls. Oxygen diffuses through them into the blood supply, and is then transported around the body.

The heart-lung machine, instead of having blood vessels, has tubes with semi-permeable membranes, which allow oxygen to diffuse into the blood and carbon dioxide to diffuse out. It also has a pump to take over the heart's function.

When the machine is connected, it bypasses the heart and lungs until the new heart is working.

INTO THE FUTURE

NOT TOO HARD TO SWALLOW



Joe Lawrence

▲ *Microelectronics will allow a video camera and even a surgical laser to be shrunk into a capsule small enough to be swallowed or injected into the body.*

▲ *Once inside the patient, the video camera pill will travel around the body under its own power, through the digestive system or the blood vessels.*

▲ *Having found the trouble spot, the camera will show the problem on a monitor screen to a doctor. Advanced versions will be controllable to perform surgery on site.*

ROBOTICS

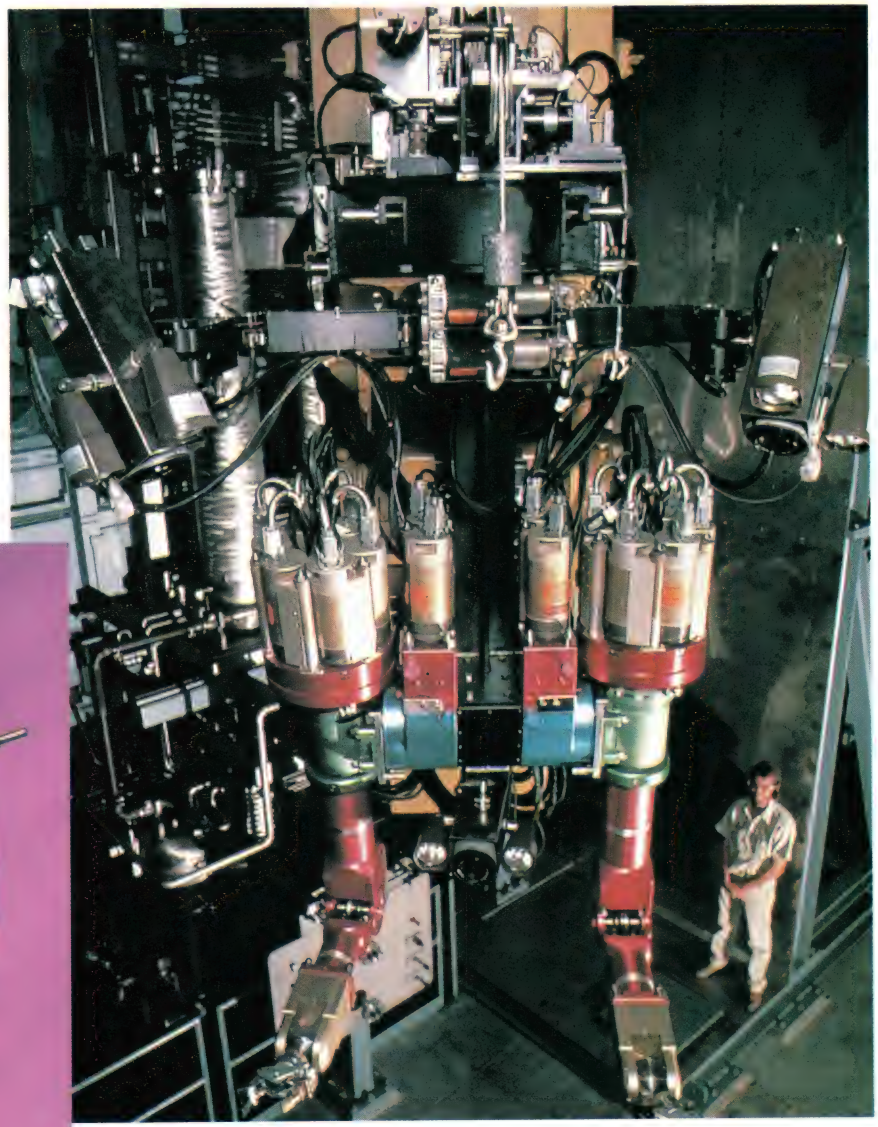
MOST FICTIONAL ROBOTS are depicted as mechanical people, with almost human qualities – think of robots and you think of C3PO or R2D2 from *Star Wars*, or *RoboCop*. But today's robots usually bear no resemblance to any human form at all.

It was the Czechoslovakian author, Karel Capek, who coined the word 'robot' (from the Czech word 'robota' meaning slavelike work) in his 1920 play *RUR*. He conjured visions of humanoid machines carrying out everyday duties. But today, by far the most common robots are the industrial kind, playing a vital role, for example, in car assembly plants around the world.

Japan alone employs over 150,000 robots in manufacturing. Most are robot arms that weld, put together, and spray-paint the components for new cars and other mass-produced goods. Robots are rapidly taking over those jobs that human workers find either boring or dangerous.

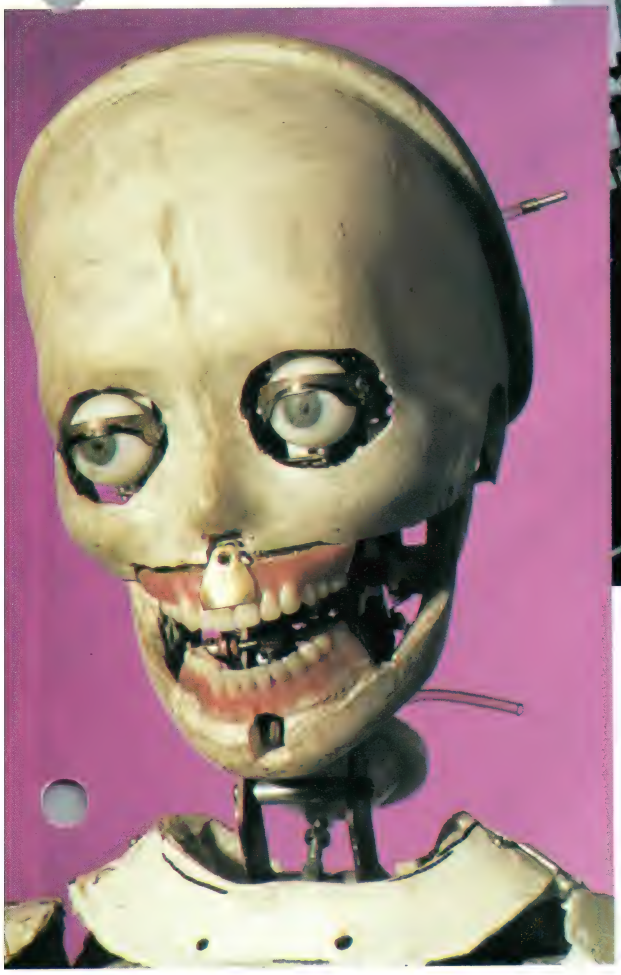
Computer-controlled

At the heart of each robot, controlling its every action, is a small computer. Before the robot can do anything at all, its computer brain must be given precise details on how to perform the given task.



Hank Morgan/SPL

The advanced servomanipulator *is a huge industrial robot equipped with video vision that can be operated by remote control. It is used at the Oak Ridge nuclear installation in the USA.*



Claude Charlier/SPL

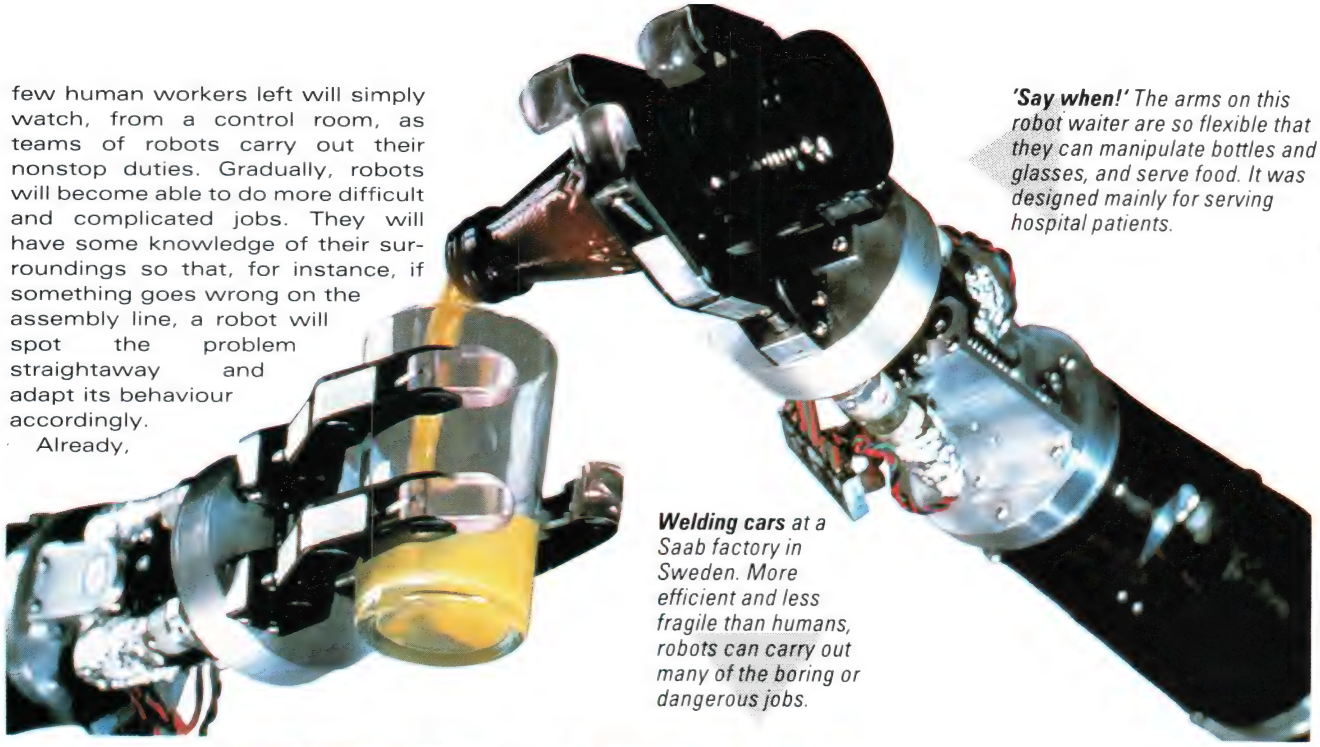
An android *is a robot that looks like a human being. This 'smiling' android was built by Mr Mizuno of Japan, who specializes in designing and building robots which resemble the famous.*

Typically, a human 'teacher' guides the robot by hand through all the actions it has to carry out. These actions are then automatically stored as a list of commands in the robot's computer. From that time on, the robot will repeat the actions exactly, over and over again, under computer control. It can be switched to a new job by giving it a new program and, if needed, a new tool for its arm.

In the future, many factories will have hardly any people in them. The

few human workers left will simply watch, from a control room, as teams of robots carry out their nonstop duties. Gradually, robots will become able to do more difficult and complicated jobs. They will have some knowledge of their surroundings so that, for instance, if something goes wrong on the assembly line, a robot will spot the problem straightaway and adapt its behaviour accordingly.

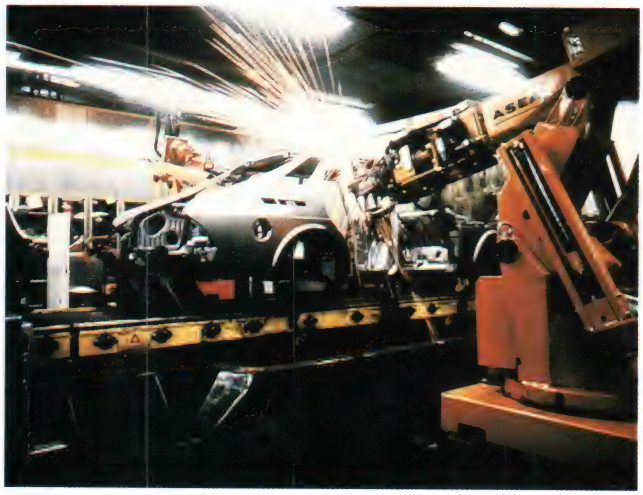
Already, robots with camera 'eyes' are being taught to recognize objects in the real world – even objects that are tilted, partly hidden, or at different distances. As humans, we take this ability for granted because our brains are so incredibly good at making sense of what we see. In robots, though, it means matching the appearance of the scene picked up by its TV camera with the appearance of known objects stored in its memory.



'Say when!' *The arms on this robot waiter are so flexible that they can manipulate bottles and glasses, and serve food. It was designed mainly for serving hospital patients.*

Welding cars *at a Saab factory in Sweden. More efficient and less fragile than humans, robots can carry out many of the boring or dangerous jobs.*

Tadanori Saito/SPL



Look, no hands! *At Rover's car plant in Longbridge, UK, robots shape and assemble engine parts. They take in raw metal castings, machine them to the required shape and assemble them. The components are transported by Automatic Guided Vehicles (AGVs) – these follow underfloor cables and are controlled by a supervisory computer.*

Saab-Scania/SPL

Rover Group

Home helps

With improved senses and a more 'intelligent' electronic brain, experimental robots are able to do useful chores around the home – a dream of science-fiction writers for over 50 years. Dusting or washing dishes hardly seem like complex tasks. But try to describe them in detail to a machine and you find that they are made up of thousands and thousands of tiny separate steps. Also, the tasks may change slightly from day to day. Different dishes need washing, or toys need moving before the carpet can be vacuumed. For these reasons, practical home robots will not become a practical proposition until next century.

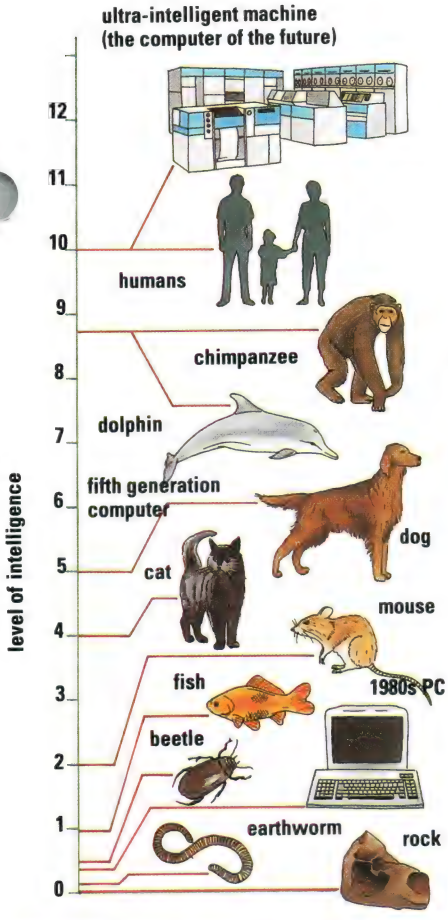
By then, intelligent robots will roam across the ocean beds in search of valuable minerals. Others may be at work in nuclear power stations, handling radioactive substances, and doing other hazardous jobs like fire-fighting.

Artificial people

Science fiction writers predict that in the future, robots may be built that look and act almost the same as humans do. Called androids, these artificial people might eventually work and live among us as equals. There could even be a 'bill of rights' protecting the interests of robots and a law to stop any android from being disconnected.

The use of more intelligent, or 'smart', computers wil greatly improve the performance of space probes. As the distance from Earth

Paul Raymonde



Brain power. *This table shows the intelligence levels of man, machine and animals. The numbers on the scale are not IQ values but are intended to give the relative brain power of each category.*

Android *version of the Beatles, at the Rock Circus in London. All of the models are controlled by computers.*

Rock Circus

increases, it takes longer and longer for radio signals to travel to a probe from mission control. The use of smart computers will enable probes to carry out complex investigations, making on-the-spot decisions as conditions change.

Smart computers will be installed in the robot vehicles being designed to explore Mars early next century.

But while robots become more and more like their human creators, there is still a major stumbling block, which is proving difficult to overcome. Computers do not 'speak' or understand human languages. They have to be given instructions in special programming languages that are very different from, for example, English. Teaching them to understand the sort of natural language by which humans normally communicate is an incredibly difficult task.

Caroline Brodie

Computer chess games *are now able to beat human grandmasters. The top computers calculate nearly one million moves per second.*

Ian

Robot toys *are as popular as the real thing. Just as industrial robots have become more sophisticated every year, so too have the toy versions.*

Hank Morgan/SPL

Robot teachers *can be fun. Omnibot 2000 has been used in schools and by the UK's Department of Transport to teach children about road safety. Commands can be sent up to 20 metres by remote control.*

Tomy

Voice synthesizers

For some years now, even small computers built into educational toys have been able to synthesize normal speech from electronically stored sounds. But the reverse process of voice analysis is very much harder to achieve. To start with, no-one speaks in exactly the same way. Even when speaking the same word, each of us makes a slightly different pattern of sound waves in the air.

On top of this, there are the complexities of human language itself. For instance, in the three sentences, 'Go right to the top', 'Move your right hand', and 'I think you are right', the word 'right' is used in a completely different way each time. We understand this because of the context in which 'right' is used. But how is a computer supposed to know? There are thousands of other ambiguities like this in English, and in other languages, which a computer has to be made aware of before it can properly analyse speech.

Translating machines

At present, computers using even the best voice-analysis programs only work if they are spoken to slowly, clearly, and using just those words that the computer has been taught to recognize. In Japan, for example, a translation machine called Atlas has been developed by Fujitsu that can convert 4,000 Japanese spoken words into English. The company is also working on a system that recognises continuous speech with different pronunciations and speeds. In Britain,

Philippe Plailly/SPL

Voice analysis *is one of the last barriers to more human-like robots. Much research is going on into voice-recognition systems.*

Logica and British Telecom are experimenting with a railway timetable that gives information over the phone. The system, known as Vodis, asks callers to repeat themselves if it cannot understand what has been said.

Intelligence

Today's brightest computers certainly fall well short of the average dog or cat in terms of intelligence. They may calculate millions of times faster than us, but in most other respects they are still surprisingly stupid! However, new ways of programming are being developed to boost artificial intelligence.

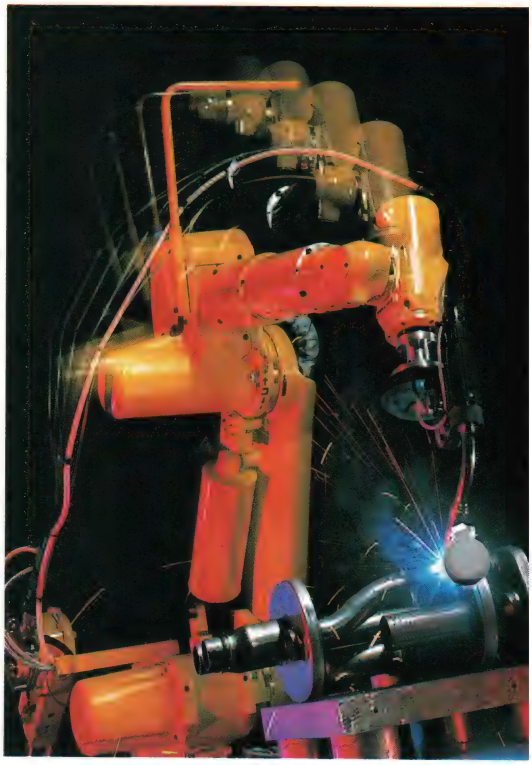
Computers can now be fed with rules of thumb, known as heuristics. In other words, the computer can make use of tips and advice from a human specialist covering some particular area of knowledge. The resulting 'expert system' can aid doctors, for instance, in identifying certain, less common kinds of illness or in selecting medicines.

Other expert systems are helping in the search for oil and valuable minerals, or even in the design of new computers. In November 1988, a computer called *Deep Thought* became the first machine to beat a human grandmaster in a chess tournament. The most modern chess playing robot can select the perfect move by searching over one million each second.

Yet, expert systems have proved less of a breakthrough than originally expected because they simply regurgitate the knowledge fed into them. Future intelligent machines will be able to learn from past experience, remembering their mistakes so that their performance gets better as time goes on.

One very promising approach being studied now is to build electronic circuits that mimic the way our own brains work. A so-called 'neural computer' will be able to try out different connections in a network of artificial brain cells until it settles on one that calculates the right answer. In areas like understanding human speech and recognizing images, neural computers will be much more adept than even the most powerful computer today.

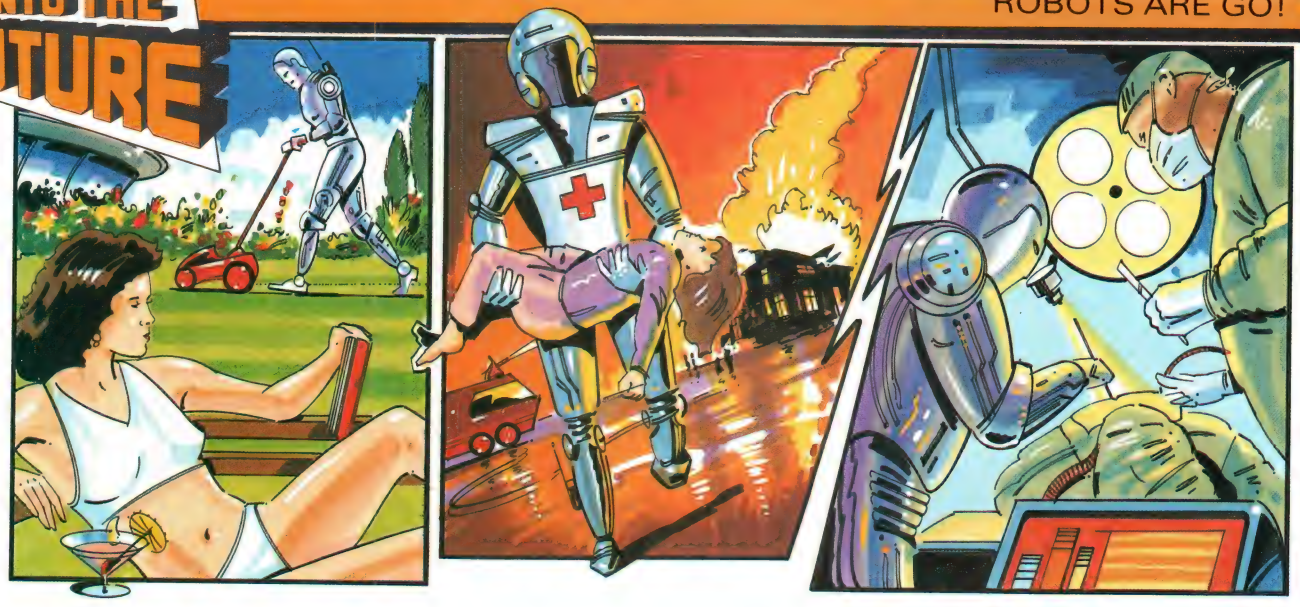
Arc welding *by robot is far more precise than human handiwork. This computer-controlled robot is welding a car exhaust.*



David Parker/600 Group Fanuc/SPL

INTO THE FUTURE

ROBOTS ARE GO!



Joe Lawrence

▲ As robots become more advanced, they will be able to perform household chores, such as hoovering, washing-up and mowing the lawn.

▲ But robots will also have more important functions with the emergency services, such as fighting fires, defusing bombs, or even carrying out rescues.

▲ Robots will also be able to perform some types of surgery with great precision – although still under human supervision.

MEMORY BANKS

- TYPES OF MEMORY
- BACK-UP SYSTEMS
- OPTICAL STORAGE

A SPECTACULAR ADVANCE in computers has been the size and speed of their memories. If cars had progressed as much as computers over the last 40 years, then a car today would cost less than 10 pence, go 500,000 km on a litre of petrol and travel at five times the speed of sound.

The memory of a computer stores data and program instructions – information the computer needs to do calculations and other tasks. There is an internal memory and an external memory.

The internal memory is like the shelves in a department store, holding items that can quickly be taken out or put back. The external memory – also called a store or storage device – is more like a warehouse. It can retain a much greater amount of information.

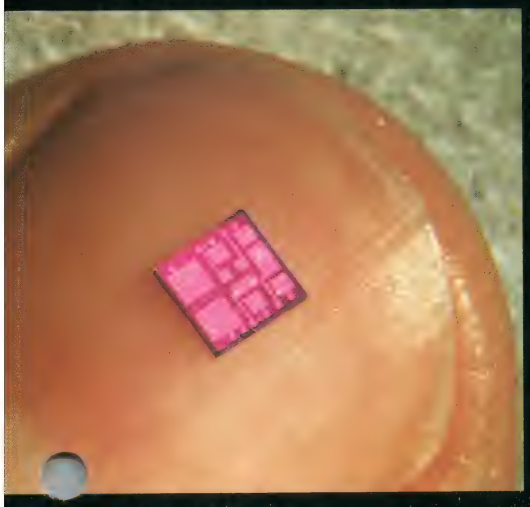
Bits 'n' bytes

Every number, letter or other symbol 'known' to the computer is represented as a 'byte' - a code made up of eight elements or 'bits'. The word 'bits' comes from *bi*nary digi*ts*, because binary is the arithmetic used to program computers. In binary there are two digits – 0 and 1.

A computer's internal memory is in the form of chips – silicon wafers etched with electronic circuits and encased in plastic. Internal memory can be either RAM (Random Access Memory) or ROM (Read Only Memory).

Any programs or data you enter at a keyboard are stored in RAM. You can put information into RAM 'write to it' or find out what is in it

SPL



***Too small to handle** – this minuscule chip has been tested and is ready to have its connections soldered on before being enclosed in plastic.*

David Parker/SPL

***Testing the circuits** on all the chips on a piece of silicon. Faulty components are marked in ink, then the silicon is baked to harden the ink so that defective chips can be identified and discarded.*

COMPUTERSPEAK – LANGUAGE OF THE FUTURE

BASIC: one of the 'languages' used to give instructions to computers. It comes from **B**eginners' **A**ll-purpose **S**ymbolic **I**nstruction **C**ode.
binary: a number system based on the two digits 0 and 1 (equivalent to the 'off' and 'on' of electronic circuits)
bugs: errors in a program
disc (disk): plastic or aluminium platter with magnetic coating on which data are recorded
hardware: the physical parts of your computer
hex: short for 'hexadecimal' – a number system based on the digits 0 to 9 and the letters A to F
interface: an electronic circuit with connecting leads and plugs for linking peripherals, such as printers and disc drives, to a computer
IT: short for **I**nformation **T**echnology
K: short for 'kilo' (1000)
peripheral: any device you connect to a computer, such as a printer.
program: step-by-step instructions that a computer follows to solve problems
software: programs or instructions that tell your computer what to do
VDU: monitor or TV screen – from **V**isual **D**isplay **U**nit

'read it', and you can change the contents. Information the computer needs to carry out your instructions is stored on ROM chips.

Built-in programs

For example, a program on ROM instructs the computer to print letter 'A' on the screen when you press the 'A' key, and graphics software lets you draw pictures on the screen. These programs are

David Parker/SPL

built into the computer at the factory. You can read them (which you do when you use them) any number of times, but you cannot alter their contents. This is important as the internal programmes are extremely complex. If a single digit is changed by accident, the entire programme is disabled.

Every year, chip manufacturers squeeze more and more storage capacity on to each RAM chip. Today's personal computers use either 1, 4 or 8 megabyte RAM chips. RAM capacity is increased by installing sets of chips side by side.

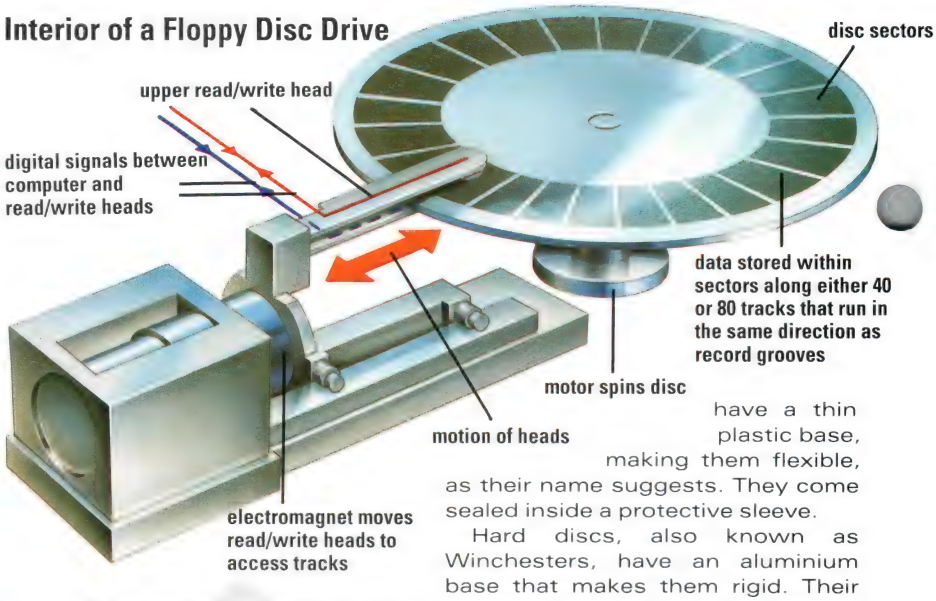
No room

Even a million bytes of RAM are not enough for some computing tasks. And there is the added problem that all of the information stored on RAM disappears if the power is turned off. This is the reason computers are equipped with external storage devices, such as disc drives.

Disc drives store data on magnetic discs as strings of north and south poles. Discs come in two forms: floppy and hard. Both have a magnetic coating similar to that of an ordinary cassette tape, and spin around rapidly beneath the recording head of a disc drive. Floppies have a thin plastic base, making them flexible, as their name suggests. They come sealed inside a protective sleeve.

Hard discs, also known as Winchesters, have an aluminium base that makes them rigid. Their magnetic coating is much thicker than that of floppies, giving them a much greater storage capacity. Hard drives of over 200 megabyte capacity are common today, and the largest computers boast Winchesters with a capacity of billions of bytes.

Interior of a Floppy Disc Drive



Chris Lyon

***A floppy-disc drive** spins the discs like an audio turntable and records data in sectors and tracks. An index hole in the disc marks the start.*

***An automated library** of computer tapes at the Fermi Laboratory in the USA. A robot finds the required tapes and files them again after use.*

Pits and blanks

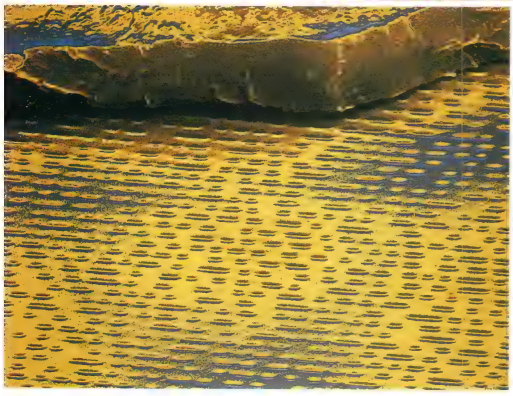
An alternative computer external storage medium is provided by compact discs (CDs) – as used for music recordings. CDs store digital information in the form of tiny pits and blanks on the shiny surface of 12-cm metal discs. By scanning the mirror-like surface, a laser beam can extract the coded information from it at great speed.

Erasable discs

One of the drawbacks of early compact discs is that, once written on, they cannot be erased and overwritten. But read/write discs are now available. Also, a new kind of optical disc is being developed which will be erasable, so you can write on it, erase and rewrite again and again.

***Compact discs** like those used for music recordings are being developed for storing computer data because they have a very large storage capacity. They store data as tiny surface pits and blanks (below).*

Etienne Poupinet/Jerrican



Dr Jeremy Burgess/SPL

Paul Raymonde

***Sci-fi worlds** can be speedily created by computer graphics systems (including paintbox and 3D solid modelling systems).*

Telegraph Colour Library

VIDEO ART

- HI-TECH GRAPHICS
- PICTURE ELEMENTS
- SYNTHESIZERS

WHAT DO *GHOSTBUSTERS, Return of the Jedi* and *Tron* all have in common? The answer is that each of these blockbuster films includes scenes that a computer helped to create. What's more, the computer-generated action looks so convincing that it fits in perfectly with the rest of the movie!

Powerful computers and advanced programming techniques have been combined to produce some amazing graphic effects. Pictures emerging from today's computers can be as clear as a photograph and nearly lifelike in appearance. The computer can draw any object or scene, no matter how fantastic.

Twenty minutes of the film *The Last Starfighter* were produced entirely on one of the fastest computers in the world. Those 20 minutes of computer animation show a rocket-powered car blasting off from Earth, then soaring through the clouds and out into space. They show battling starships and strange alien planets. To produce these special effects using hand-crafted models would have cost between £7–14 million. But with the aid of a supercomputer, these thrilling action scenes were made for just over £2 million.

Pixels and rasters

The commonest way to show computer-generated pictures is with a special graphics monitor. The computer divides the monitor screen into a patchwork of dots or pixels (short for 'picture elements'). Then it decides which of these pixels should be turned on or off at any given moment. The complete pattern of pixels on the screen is known as a raster.

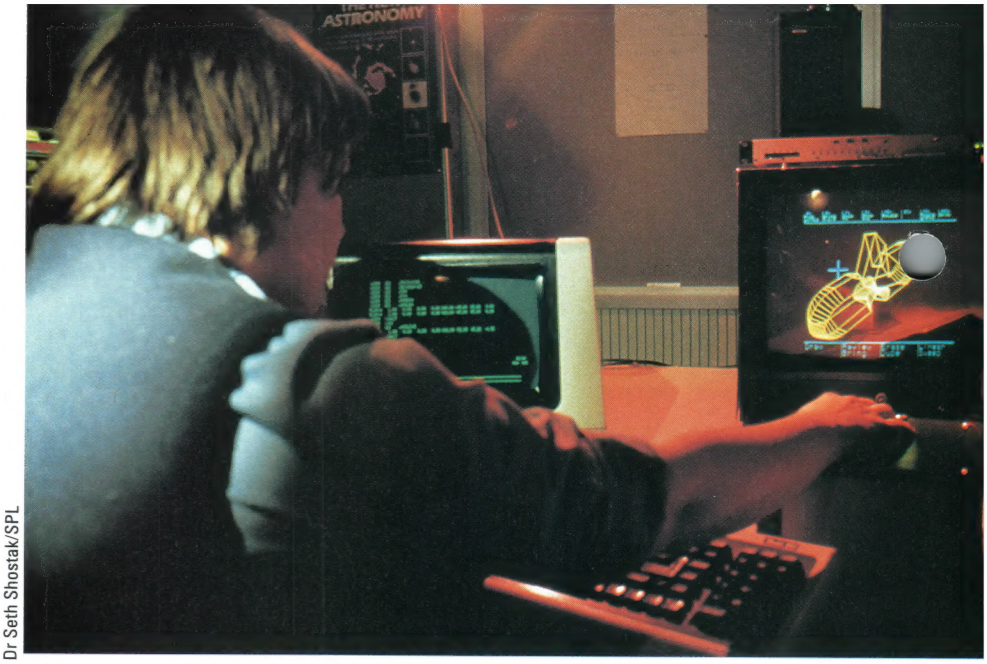
About 30 times a second, all the pixels in the raster are redrawn. That way, the screen display never fades or flickers. A beam redraws the raster each time, starting at the upper left-hand corner of the screen, darting rapidly along a zig-zag track and ending at the right-hand corner. Then the beam races back along the shortest possible path to its starting point, to begin its split-second journey all over again.

Special effects

The more pixels there are on the screen, the sharper the resulting graphics image. But just how many pixels can a computer handle? That depends on the computer's size and speed. The brightness and colour of each pixel is managed by a small chunk of the computer's memory. So, to handle more picture elements you need a computer with a larger memory. And if you want the picture to change quickly or in a complicated way, the computer must also be able to work at high speed.

Another classic film featuring

Computer graphics is Clarke's *2010*, in which much of the action takes place near the planet Jupiter. Filming on location would have posed quite a problem for the film's producers! So instead they turned to a Cray supercomputer to depict what Jupiter might look like from a passing spacecraft. Starting with actual photos of Jupiter taken by the Voyager probes, the filmmakers used the Cray to add extra colour, detail and cloud movements. Several trillion calculations had to be carried out for each second of finished film and, when complete, *2010* included 130 seconds of Jupiter animation.



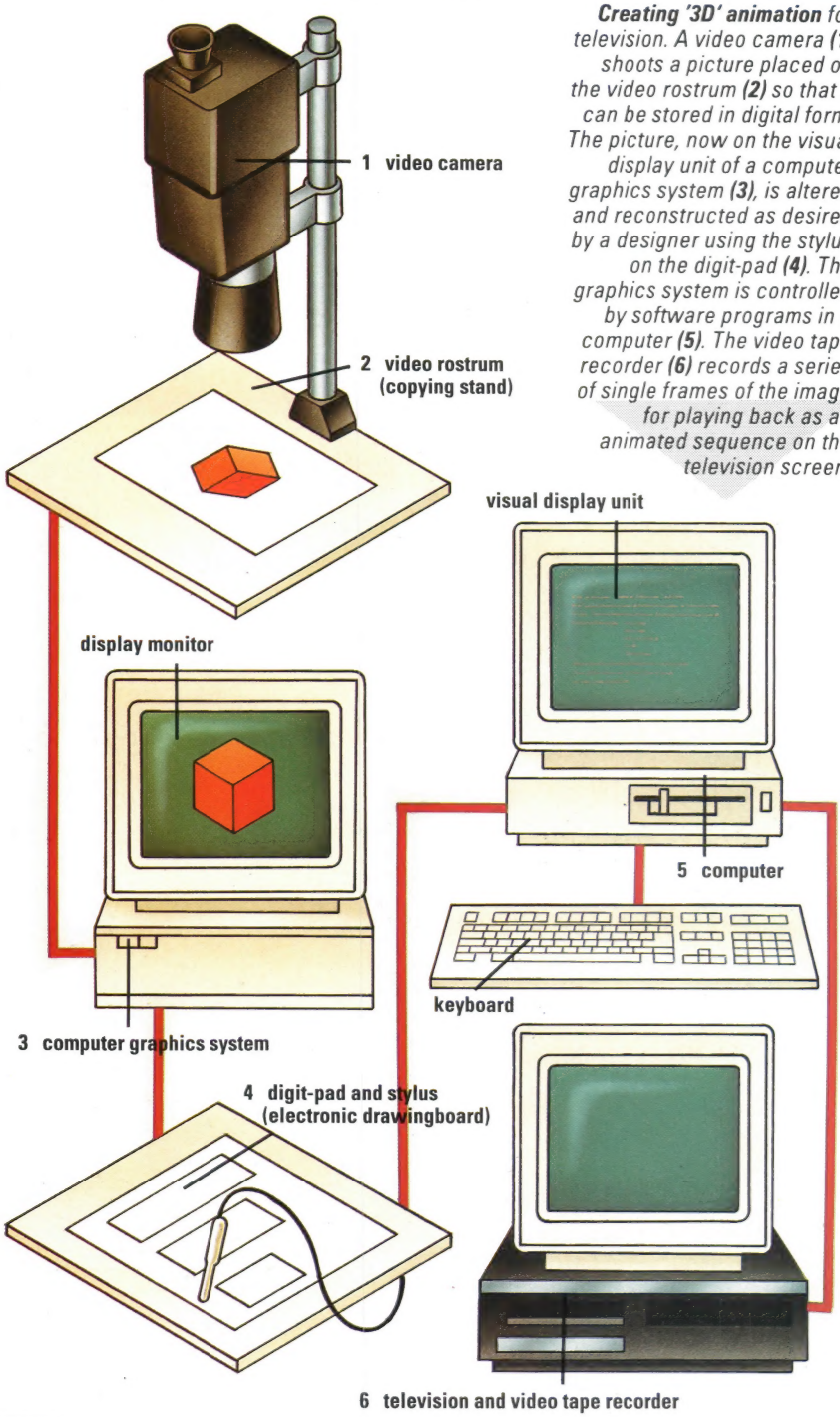
Dr Seth Shostak/SPL

Ray tracing

Over £1 billion a year is now spent on computer graphics for film and television, world-wide. Computer-generated special effects can be intermixed with live action so well that the viewers simply can't tell the difference.

Using the latest graphics programs, lifelike textures and shading

Creating '3D' animation *for television. A video camera* ***(1)*** *shoots a picture placed on the video rostrum* ***(2)*** *so that it can be stored in digital form. The picture, now on the visual display unit of a computer graphics system* ***(3)****, is altered and reconstructed as desired by a designer using the stylus on the digit-pad* ***(4)****. The graphics system is controlled by software programs in a computer* ***(5)****. The video tape recorder* ***(6)*** *records a series of single frames of the image for playing back as an animated sequence on the television screen.*



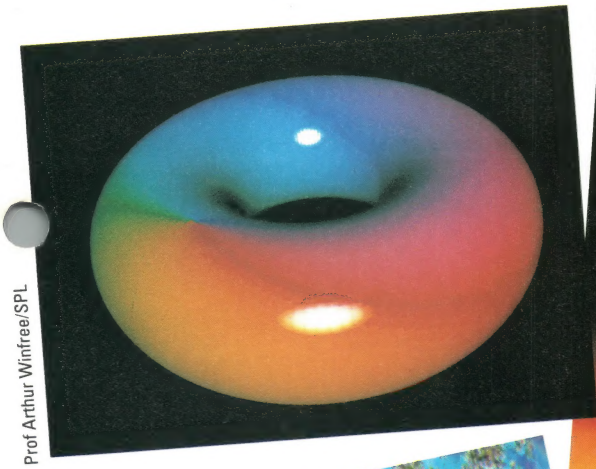
Mark Franklin

The new 'designer-friendly' *computer graphic systems can be operated with no previous knowledge of programming.*

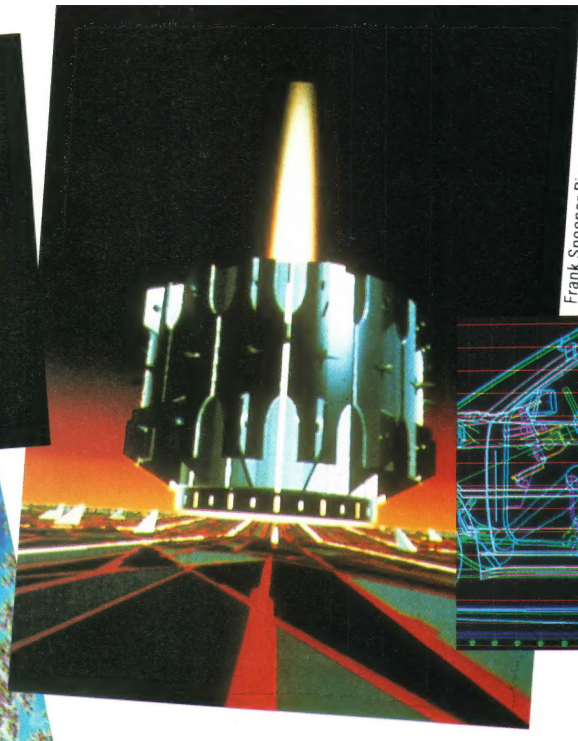
ON-SCREEN ART

Ducros/Jerrican

Computer graphics generally have a smooth and regular quality. But patterns found in nature, such as a coastline, or the surface of a mountain, are usually rough, uneven and irregular. Dr Benoit Mandelbrot, a mathematician, has identified shapes that he has called 'fractals' (from the Latin word fractus meaning broken): curves with branches, which link together to form irregular lines. One use of fractals is to create highly detailed geometrical patterns. Another is to create a landscape – the artist programs a computer with fractal formulas that will throw up a variety of semi-random structures, which are ideal for depicting, say, the shore of an island, the course of a river or even the Earth's surface as depicted above. From these the artist can elect the one that is just right.

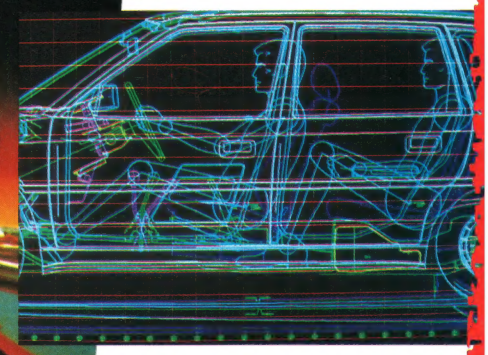


Prof Arthur Winfree/SPL

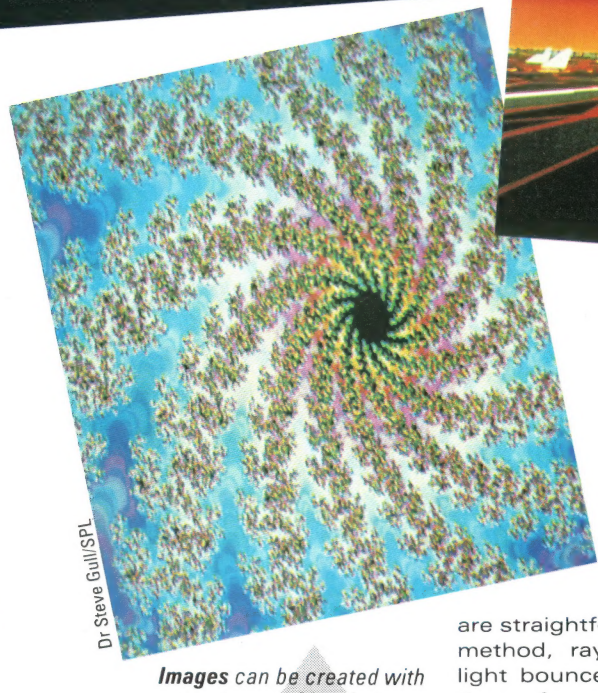


Frank Spooner Pictures

Engineers *use computer graphics to check calculations on how parts of a new product, such as a car, might perform.*



Berenguier/Jerrican



Dr Steve Gull/SPL

Images *can be created with computer graphics that vary from smooth three-dimensional curves (top) to complex geometrical patterns (above).*

A graphics system *with very high resolution output – 800 lines per centimetre on the screen, for example – can produce a very sharp image.*

are straightforward to produce. One method, ray tracing, lets rays of light bounce off (or pass through) the surface of objects in the computer graphic just as they would off real objects.

Computer graphics are extensively used on television. One feature now in common use is digital television picture manipulation, using systems such as Quantel Graphics Paintbox. A moving television picture is reduced, enlarged, flipped (turned over), overlapped, merged, folded, exploded, dissolved and distorted in a sequence controlled by a computer program. Graphics displays at the beginning of television programmes are often produced in this way.

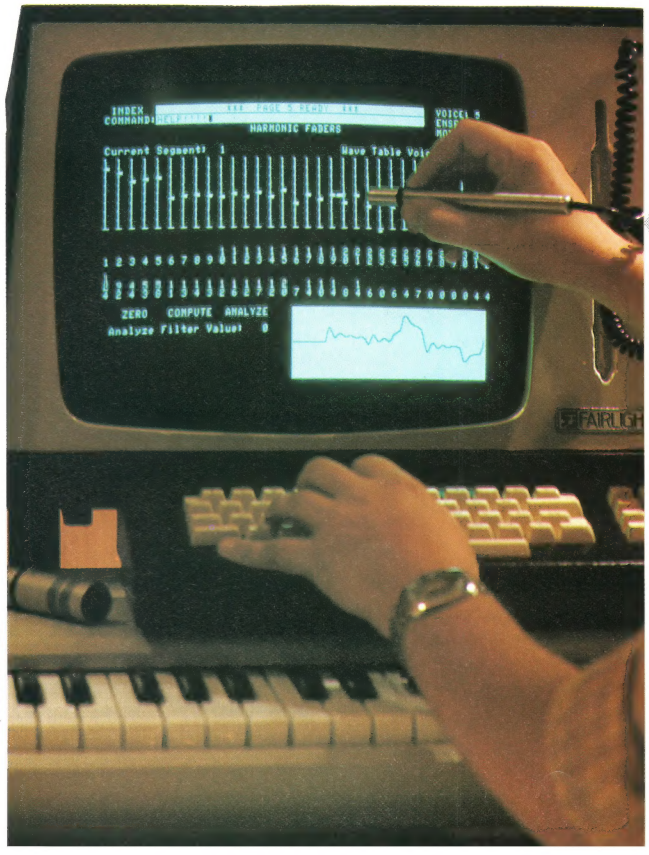
The computer-scope

High-performance computer graphics are also finding a multitude of practical uses in science and industry. Through them, researchers can investigate, for instance, how new chemicals and drugs will work.

In effect, the computer becomes an enormously powerful microscope. It shows by detailed moving pictures how the individual molecules (the tiny 'building blocks') of a new drug, for example, join up like a key in a lock with other molecules inside a person's body. Hoping to find a key that will work even better, the researcher can try a drug with a slightly different molecular structure. Another look through the 'computer-scope' then shows what the effect of the change has been.

Simulators

A special kind of computer employs graphics to help train aircraft pilots. Called a flight simulator, it is connected with all of the instruments in a mock-up of the plane's cockpit. The 'windows' in front of the trainee pilot are actually large display screens on which the computer recreates the view, from instant to instant, that the pilot would get if it were a real plane in flight. Accurate details of the runway layout of dozens of major airports around the world may be stored in the simula-



Taquet/Jerrican

The Fairlight CMI *(Computer Musical Instrument) is one of the best synthesizers in the world. You can draw the exact waveform you want directly on to the computer screen using a light pen. Unlike many other synthesizers, instructions are entered through an alphabetical and numerical keyboard.*

tor's memory. To add to the illusion, simulated flights can take place by day or night, and in clear weather or fog.

Keeping time

In a small room at the Media Laboratory in Cambridge, Massachusetts, USA, two people, a violinist and a flautist, play while a third conducts. The accompanying melody of another instrument, such as a harpsichord, comes from a computer-controlled synthesizer that has been programmed with all the details of the musical piece it has to play. But how does the synthesizer manage to keep in perfect time with its human counterparts?

The secret lies in a special device that follows the movement of the conductor's baton. This device passes on all the information on timing that the computer needs so that it can 'play' the synthesizer. Using such equipment, orchestras of the future could include both human and computer members.

In the future, musicians and composers will use computers more and more. Already, a lot of pop music is composed and recorded with the help of computers and synthesizers. A computer can store digitally the elaborate pattern of sound waves, say, from a guitar or a drum. Then, on demand, it will send this digital signal to a synthesizer to recreate the original sound. In other cases, the computer and synthesizer can generate totally new sounds never heard before.

In recording studios, computers are being used to 'take apart' the sounds from hit records of the past. A particularly good drum part, for instance, might be 'sampled' from a golden oldie of the 1960s and combined with a recent guitar and voice recording in the hope of making a new hit.

Computers can even write poetry. A collection of words is fed into the computer together with rules for combining those words.

Writing stories

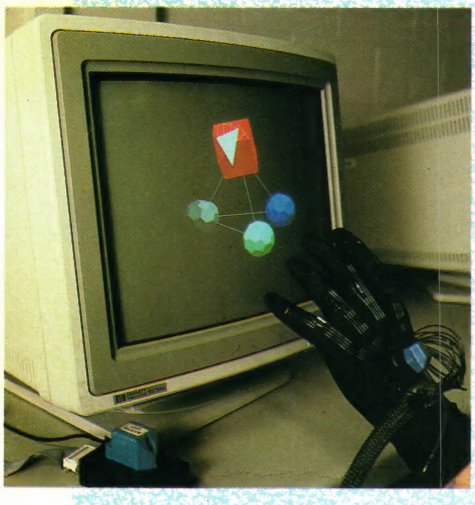
A class at the University of Wisconsin managed to program a computer to create short mystery stories, as an experiment. Each story was about 2,000 words long – and took about half a minute for the computer to write!

Rediffusion Simulation

Rediffusion Simulation

Flight simulators *can be incredibly realistic. Looking through the 'windows' of the cockpit – actually screens showing computer graphics – the pilot even has the chance to react to animated images of other aircraft, both on the ground and in the air (right). In addition to helping pilots learn flying techniques, flight simulators are very useful when a pilot has to get used to a new type of aircraft.*

MOVING PICTURES



Media Laboratory/Massachusetts Institute of Technology

Wearing a Dataglove, you can 'grip' three-dimensional objects on a computer screen, lift them, move them around and even throw them so that they bounce. How is it done? Your hand inside the glove moves around in a magnetic field in front of the screen. A device the size of a sugar-cube on the wrist of the glove detects changes in the magnetic field as the hand moves through it. The computer reads the changes and transfers the glove's real position at any moment to that of an animated glove on the screen.

Just amazing!

FUTURE MASTERPIECE?

COMPUTERS COMPETE WITH HUMAN AUTHORS IN WRITING BOOKS BUT THEIR TITLES ARE LESS THAN INSPIRING, SUCH AS 'THE POLICEMAN'S BEARD IS HALF CONSTRUCTED'.

Paul Raymonde